QUANTIFYING ADDITIVITY BETWEEN LIGHTING SCHEDULES AND FEED FORM ON BROILER METABOLIC EFFICIENCY

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METABOLIC EFFICIENCY

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CHAPTER I

INTRODUCTION

BACKGROUND

As the world's population enters this new millennium, stark contrasts become apparent between the availability of the natural resources of our earth and the billions of humans who require them for their survival (Pimentel 2004). Indeed, the availability of natural resources that support human life, such as food, fresh water, quality soil, energy, and biodiversity, are being degraded or polluted, and some are being depleted by natural disasters and drought which has the potential to create a food shortage. To alleviate that food shortage global corporations are changing to contribute to the production of relatively inexpensive foods, such as chicken and other meat. Additionally, abundant arable land and water resources, in conjunction with viable government production and trade policies, could encourage feedgrain and oilseed production, which in turn would enhance the initiation of a viable domestic poultry industry (Taha, 2001). In recent decades, changes in the technologies of crop and animal production have been expanding as small family farms are disappearing and being replaced by large farms to meet world demands for food.

GLOBAL TRENDS

Higher income, urbanization, other demographic shifts, improved transportation, and consumer perceptions regarding quality and safety are changing global food consumption patterns (USDA, 2006). Worldwide, total meat production has more than tripled from 71.2 million tons in 1961 to 237 million in 2001. More importantly, poultry meat production has the fastest annual growth rate nearly doubled that of pork, 3.4 times that of sheep and goat meat, and 6 times that of bovine meat (Taha, 2001). World poultry meat output increased nearly eightfold, from 8.9 to 70.4 million tons from 1961 to 2001. Most of this production is concentrated in a few countries with the USA representing 24%, China 18.5% and EU 14% of the world production (USDA, 2006).

BROILER MEAT PRODUCTION AND CONSUMPTION IN THE USA

The United States poultry industry has largely grown from small backyard operations in the early 1900s, when chickens were strictly a by-product of egg production, to a vertically integrated industry. The transformation of poultry production from a backyard activity to a multibillion-dollar industry has been made possible by using discoveries in basic biology to solve technological barriers to intensive poultry production Etches (1998).

In 1950, between 12 and 14 weeks were required to produce a 2 kg chicken now only six weeks is required to produce that same weight. Initially, the selection of broilers was for greater growth rate and meat yield, but as excessive carcass fat became a problem the emphasis changed to improving feed efficiency as well.

Today U.S. broiler production is expected to grow by more than 2 percent in 2006 to 36.2 billion pounds. So far production in the first quarter of 2006 was estimated at 8.9 billion pounds, up 3.6 percent from the previous year Haley (2006). Contributing to that increase in production is the number of birds slaughtered and the average live weight of birds. Broiler meat production is expected to slow in the second and third quarters in response to the low prices seen for almost all broiler products. To help keep prices from reducing the number of chicks being placed for grow-out has been slightly lower than the previous year. Nonetheless, total broiler meat production is expected to be higher for the next several quarters due to increases in the average bird weight at slaughter. Compared to other meat, there is a higher demand for poultry meat due to its lower cost relative to beef and pork (Haley, 2006).

U.S. consumption data indicate that per capita consumption of red meat and poultry has increased since 1970. The average American consumes 124 kg of meat and 20 kg of fish per year. Of the meat eaten, poultry amounts to 48 kg, beef 44 kg, pork 31 kg, and other meats 1 kg, (Pimentel and Pimentel, 2003). Most of the increase is accounted for by poultry consumption, while consumption of beef has decreased. Hypotheses have been proposed to explain the substitution of poultry in place of beef consumption. Changes in consumers' preference may be based on health concerns. Moreover, many people have busier schedules and may either be unable or don't have the time to cook therefore they can switch to more timesaving poultry dishes in place of more time/labor intensive preparation often necessary with beef. Another explanation for increased poultry consumption focuses on higher beef prices relative to poultry, and the simple tendency for consumers to choose greater quantities of lower priced goods.

POULTRY TRADE

For the period January-February 2006, the largest importer of US broiler meat was Russia, that totaled 283 million pounds, followed by Mexico. The combined demand of China and Hong Kong ranked third among the major importers while the Caribbean islands were the fifth largest export market for U.S. broiler products, (Haley 2006).

Significant challenges lay ahead for the US broiler industries, as other major broiler exporting countries increase production. U.S. producers are expected to face strong competition from Brazil in the coming years, (Taha, 2001). Another challenge is the falling demand from foreign markets in response to Avian Influenza ("bird flu"), an infectious disease of birds caused by type A strains of the influenza virus that reduced poultry meat exports for the fourth-quarter 2005 and first-quarter 2006 (Haley, 2006). Yet increased poultry meat production per capita, varied widely among countries according to GDP income levels (SCAHAW, 2000). Per capita consumption of poultry meat grew faster than pork, bovine (beef and water buffalo), lambs, goat, and other meat. Internationally poultry consumption was also dependant on income. Consumption was faster (635 %) in middle-income countries than in high- and low-income countries (370 %) Taha (2001).

BROILER WELFARE

The rapid growth of the broiler results from genetic selection, intensive feeding and management systems. However, this may be the main cause of several maladies such as skeletal disorders, metabolic diseases and Sudden-Death-Syndrome (SDS) (Julian, 1998). Also it is widely believed that leg problems are the principal factor detrimentally affecting broiler health and welfare. The European Commission's Scientific Committee on Animal Health and Animal Welfare (SCAHAW) reported that leg disorders were a major cause of poor welfare in broilers SCAHAW (2000). A gait scoring system has been implemented and is sometimes used to assess the walking ability or disability presumably from pain or discomfort that is experienced by the bird. However, the subjective nature of the scoring system leads to difficulties in making direct comparisons between different studies and there is a strong need to develop objective measurement systems and to carry out systematic epidemiological studies SCAHAW (2000).

Increasing breast muscle yield has caused broilers' centre of gravity to move forward and breasts to be broader. These changes also affect walking ability, gait and mechanical stresses on legs and hip joints. Accelerated skeletal growth has led to an increased incidence of bone disorders, most resulting from growth plate pathologies SCAHAW (2000).

Sudden-Death-Syndrome (SDS) is an acute heart failure condition that affects mainly fast growing male birds, and breeders nearing peak egg production otherwise in generally good condition. Even though the apparent time from onset of the syndrome until death occurs in broilers is only a matter of minutes, it may still have an important impact on bird welfare. The SDS in breeder hens is progressive aside from genetics and nutrition; environmental conditions can influence the incidence of ascites and SDS. The fast growth rates increase the risk of ascites and SDS by increased oxygen demand of the broilers, which intensifies the activity of the cardio-pulmonary system. Since growth rate and oxygen demand coincides with other physiological challenges in the young chick (e.g. change in the thermoregulation), this may lead to failure of cardiac function.

As a management tool, it would appear that increases in growth rate could be greatly facilitated if the capacity of the cardiovascular and pulmonary systems can be increased.

In terms of management, feed form and light restriction has had positive impacts on broiler performance.

The past sixty years has brought about several significant discoveries in the fields of nutrition and management. These discoveries have different have impacted considerable progress for the poultry feed industry. One of these discoveries is the effect of feed form on broiler performance. The advantages and disadvantages of pelleting versus mash have been thoroughly evaluated (Calet, 1965, Kilburn and Edwards, 2001) during that time. However, in terms of bird performance, more recently, (Mc Kinney and Teeter, 2000) established the caloric value for pellet vs. mash respectively.

Controlling the feed intake of broilers is a common practice that gives better control of growth and to enhance feed efficiency (by minimizing feed wastage and exploiting compensatory growth). Similarly, if growth control is properly implemented, livability and leg health may sometimes be improved. One way of controlling feed intake is to manipulating the hours of daylight although there are some problems associated with this process. In the breeder bird, as growth rate increased through genetic selection, it became necessary to impose progressively more severe food restriction on parent stock (breeders) during rearing, to control body weight at sexual maturity. Food restriction continues in a more mild form throughout adulthood. As a consequence of this restriction and suppression of body weight gain, the behavior and physiology of breeding birds differ markedly from those on ad libitum -fed consumption SCAHAW (2000).

Even with ad libitum feed consumption, male and female birds perform different. After about the first 2 weeks of life, the feed conversion ratio (FCR of female broilers is greater than that of males, regardless of whether sexes are compared at the same age or the same body weight while the growth velocity is higher in the males compared to the females. The fast-growing and more efficient feed converter male broilers allows the bird to reach target slaughter live weight earlier than the females Veerapen (1999) In other words, females become progressively less efficient than males at converting food to weight gain throughout the production period. Research is needed that interactivity examines relationships between management (light and feed form) with bird ability to convert feed nutrients into products. Only in this manner will producers be able to alter nutrition and ration cost to optimize performance and improve their management techniques. Additionally, failure to do so could potentially produce fatter birds for the consumer if managerial improvements in feed conversion are not interacted with reduced nutrition application.

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CHAPTER II

REVIEW OF LITERATURE

ENERGY METABOLISM

Energy is not a nutrient in the sense of chemically identifiable substances, such as essential amino acids, fatty acids, minerals, or vitamins but rather an abstraction that can be measured only during its transformation from one form to another NRC (2003). Many of the process of metabolism require a source of energy to perform the work of building tissues, manufacturing eggs, and powering all the other activities of a living bird. Energy can be expressed as the ability or capacity to do work or to produce change. There are several forms of energy, all of which can be divided into two categories namely kinetic energy, which is energy in motion and includes electrical, thermal, and motion radiant energy. The other category is potential energy or stored energy and includes chemical, mechanical, nuclear and gravitational energy. In nutrition, energy in expressed in terms of calorie, which is the amount of heat required to raise the temperature of one gram of water from 16.5° to 17.5° C. 1 cal is defined more accurately as 4.184 joules (NRC, 1994). Since a comparatively large amount of energy is required in poultry metabolism, the energy unit generally applied is Kilocalorie (kcal) or Mega calorie. Ingested energy undergoes measurable changes in the conversion of chemical energy in the animals for use for tissue growth and work (Scott et al., 1982) as displayed in figure 1.

ENERGY PARTITIONING

Gross energy (GE) can be simplified as the energy released as heat when food substances such as fat, carbohydrate or protein are completely oxidized to carbon dioxide and water, (NRC, 1994). As a result gross energy is also referred to as the heat of combustion. The gross energy content of a diet can be determined by using the bomb calorimeter. Fats generally contain about two and a half times as much energy as carbohydrates, while protein has a higher gross energy than carbohydrates. Average GE concentrations of carbohydrates, proteins, and fats have been estimated to be 4.1, 5.6, and 9.4 $kcal \cdot g^{-1}$, respectively. NRC, (2003)

Numerous factors such as, protein, lipid and carbohydrate content of the diet and energy loss all affect the degree of energy retention. The gross energy does not take into account some of the feed energy that escapes unutilized and therefore lost during metabolism and digestion. GE it is not a true estimate of energy available to the animal. The loss of energy can be classified into two general groups. Firstly much of that energy will be lost in the feces as fecal energy (FE). Fecal energy is the weight of the feces times its gross energy. FE may be further partitioned into energy of undigested food and energy of compounds of metabolic origin (NRC 1981).

The Apparently Digestible Energy (ADE) of a food does not take into account endogenous losses and is estimated as the gross energy of the food less the energy contained in the feces, which results from any particular food McDonald (1995) thus the formula.

ADE = GE-FE.

ADE =   Apparent Digestible Energy, GE = gross energy, FE = Fecal energy.

Apparent Metabolizable Energy (ME) of a food is estimated as apparent digestable energy less combustible gaseous and urinary energy. It is that energy that is available for tissue assimilation and oxidation. The feed energy estimate currently used in poultry diets is metabolizable energy (ME). However, ME_n is used when corrected for zero nitrogen balance NRC (1994). The ME requirement for maintenance has been defined as the amount of energy required to balance anabolism and catabolism, giving an energy retention around zero Sakomura (2004). According to Beker (2006) the overall dietary energy value is well correlated with nitrogen retention. Therefore it is necessary to use ME_n instead of ME, when energy available to the bird independent of retention is needed.

Metabolizable energy is a reliable index of what is available to the bird for maintenance and production but not a predictor of how efficiently the bird then uses what is available (Macleod, 2000). Today's poultry industry utilizes metabolizable energy as the reference standard for ration formulation but ME is not the final amount of available energy available to the bird because about 40-60% of ME is lost as heat in growing chicks. Daskiran (2003). The type of feed and the specie of the animal can affect the metabolizable energy value of a feed. Starch is usually the largest single nutrient in feed and provides the greatest proportion of metabolizable energy. For example after barley is consumed, twice as much energy is lost in the feaces as in the urine. In the non-ruminants energy loss as methane is negligible which means that for foods such as concentrates, which are degraded to much an extent by ruminants and non-ruminants, metabolizable energy values will be greater for the non-ruminant. Mc Donald (1995).

There have been many studies conducted to estimate metabolizable energy value of feedstuffs and diets but more recently by (Ragland, et. al 1997), determined the ME of poultry and ducks respectively and (lopez and lesson, 2005) who studied the utilization of ME by young broilers.

It was noted that when chicken feaces were combusted and evaluated, it provided a means of accurately estimating the ME content of feed ingredients used to formulate diets and a good indicator of the energy that was not digested by the chicken. It was also possible to estimate the metabolizable energy value in the ruminant food from digestable energy value by multiplying by .8 which means that about 20 percent of the energy apparently digested is excreted in the urine and as methane (McDonald, 1995). In poultry it is easier to measure metabolizable energy than digestible energy, because the feaces and urine are voided together. ME for poultry is measured by fasting the birds for twelve hours until their digestive tracts are empty. The birds are then allowed to eat a specific diet and all the feces from that diet are then collected, at the same time, the small quantity of feces voided by fasted birds is collected as a measure of endogenous loss. The energy of the endogenous loss are deducted from the energy of the excreta of the fed birds, and of metabolisable energy estimate obtained is referred to as a true rather than an apparent value (McDonald, 1995): therefore

$$ME\ (kJ/d) = GE - (FE + UE + GPD)$$

ME = Rate of supply of metabolizable energy, Fe = Fecal Energy,

UE = Urinary Energy, GPD = Gaseous products of digestion.

In terms of apparent digestable energy it can be estimated by subtracting gaseous products of digestion and urinary energy from apparent digestable energy.

AME= ADE – GPD –UE.

Where AME = apparent metabolizable energy, UE = urinary energy

GPD = Gaseous products of digestion and ADE = apparent digestable energy

When the heat increment is subtracted from ME, the resulting energy value is termed Net energy. Net energy may be further subdivided (NRC, 1994) into NE for maintenance (NEm) and production or gain (NEg) (NRC, 1994). The net energy for maintenance is mainly used to perform work within the animal's body and leaves the body as heat McDonald (1995). Different approaches can be used to estimate energy retention for instance energetic balance components can be determined by direct calorimetry using calorimeters, indirect calorimetry, and by the carcass analysis. The indirect calorimetry method, measures the heat production (HP) by determining the O2 consumed and CO2 produced in respiration chambers, and has been used in several studies Sakomura (2004). While the comparative slaughter method estimates the HP by the difference of ME intake and body energy retained is sometimes used. The ability to convert nutrients to the final products depends on a variety of factors, such as age, sex, genetic and housing system. The Net energy efficiency of food may be expressed as

NEm = RE/IE where;

NEm= net energy for maintenance (kcal/g),

RE = retained energy, IE = gross energy consumed

Alternatively the effective energy (EE) can be estimated as (MJ/kg) = GE (d-0.228) – 4.67DCP, where GE is the gross energy (MJ/kg) and DCP is the energy digestibility (MJ/kg) also measured at maintenance. The EE yielded to a single stomached animal can be estimated as EE (kJ/g) = 1.17ME – 4.2CP-2.44, where ME (kJ/g) is measured at or corrected to zero N-retention and CP (g/g) is the crude protein (N*6.25) content of the feed ingredient. (Emmans, 1994). Energy may also be expressed according to effective caloric value, whereby the energy value relative to standard production systems, may be estimated (Mc Kinney and Teeter, 2003). Advantages of the later approach include the placing of caloric value and management change.

HEAT INCREMENT

Soon after food molecules are absorption from the gastrointestinal tract there is an increase in heat production, which is referred to as the heat increment and is often regarded as an energetic waste product. The heat increment represents the heat lost from biochemical reactions of nutrients at the cellular level. Heat increment includes heats of fermentation, digestion and absorption, product formation, and waste formation and excretion. It is a loss of energy unless used as a source of when the temperature in the animal's environment is below the lower critical temperature especially during the winter season. Energy expenditure can be determined directly by measuring heat output from the body but is normally estimated through indirectly calorimetry from the consumption of oxygen and the carbon dioxide production. Any change in heat increment alters ME_n utilization and thereby can affect the cellular nutrient / energy ratios.

BASAL METABOLIC RATE

The basal metabolic rate is defined as the heat production occurring by an animal at rest, awake, fasted and housed within its thermo neutral zone. BMR is the minimum metabolic rate that drives the normal physiological processes of life, such as energy required for cellular activity, respiration, circulation, nerve impulses, and maintaining body temperature (Beker, 2006). Basal metabolic rate can be determined by direct calorimetry, which is a measure of heat loss. BMR is related to an animal's surface area also surface area and basal metabolism per unit body weight decline with increasing body weight. Since surface area is a difficult trait to measure, attempts have been made to relate it to body weight (Brody, 1964)

FEED FORM

The earliest use of feed form was for non- nutritive purposes and dates back several years when early English breeders first made up their poultry mash in the form of pellet, (Calet, 1965). The purely practical aim was for simplifying food handling and reducing loss due to feed wastage. Today, most feed for meat birds worldwide is either in the form of mash, crumbled or whole pellet. However of these different feed forms pelleted feed seem to have several more benefits to poultry performance than either mash of crumbles. Conventional nutrition literature seems to point to the fact that grinding feed enhances the growth and performance of animals. It may be possible that the grinding process increases the surface area upon which enzymatic or bacterial activity can occur. Several researchers have documented that it is more beneficial to feed pellet than mash or crumbled feed. Even so not all those benefits of pelleting are always accepted.

It has been reported that pelleting improves ($P<0{\cdot}001$) weight gain from nearly 25%. (Preston et al., 2000) to 30% (Petterson et al., 1991) but there is no collective agreement on whether or not the process improves feed efficiency. For instance Choi et al. (1986) reported that pellet improved animal performance and feed conversion compared to feeding a mash diet. While Kaudia (1999) reported better performances in terms of lower mortality, feed conversion ratio, production index number and gross profits per bird placed with broilers fed on mash rations compared to those birds fed pellet. Careful scrutiny of these results may depend on several factors for example conditions of rearing, age of the birds, sex and strain, environmental temperature and lighting duration.

The improvements in bird performance from pellet has been accredited (Behnke, 1996) to decreased feed loss, reduced selective feeding, decreased ingredient segregation, less time and energy expended for prehension, destruction of pathogenic organisms, thermal modification of starch and protein and improved palatability. It has also been suggested that pellet have been more beneficial than mash merely because of particle size (Yasar, 2003). Since pellets are too large for young chicks during the first 2 weeks of age, it is unlikely that feeding a pelleted diet at that stage to chicks will be beneficial. Calet (1965) reviewed the effects of pelleting food and concluded that, a mixture of mash and crumbs is most effective at this stage however beyond the age of three weeks; crumbs or pellet are best used on their own.

MANAGEMENT AND HEALTH

While improved broiler performance is an advantage for pellet feeding, there are some disadvantages connected to this feeding method. Feeding pellet to birds on litter floors has been related to various problems. A common problem is feather pecking, which may raise the risk of cannibalism in laying hens. Cloutier et al. (2000) reported that there was a positive correlation between the frequency of severe feather pecking at flock mates and the frequency of cannibalistic behavior, which can result in injuries, and even the death of birds. Husbandry practices such as debeaking and the use of spectacles have been used in different countries with limited success. However, besides being an animal welfare concern these practices can cause infections and undue stress from handling which affects performance. The feeding of pellet has been shown to increase the risk of feather pecking Aerni et al. (2000). The authors observed laying hens fed either mash or pellet with or without access to long-cut straw as foraging material. Birds fed pellet had a higher rate of feather pecking and pronounced feather damage when they had no access to straw litter. A similar relationship between pellet and cannibalism was also reported by Savory and Hetherington (1997). From a practical point of view it can be recommend that laying hens housed without foraging material should be fed mash while those with adequate foraging material may be provided pellet instead.

The importance of water to broilers is related to its chemical and physical properties and as a solvent in the digestion and absorption of food, the transport of nutrients in the body and the elimination of waste products via the urine. Engberg et al. (2004) reported that broilers drank more water when they were fed pellet compared to a wheat diet and grounded feed. Since broilers consume more pellet than mash and there is a direct relationship between the amount of water a bird consumes and the amount of feed consumed, it can be assumed that water consumption will be higher when broilers are fed pellet. It is imperative that birds get free access to adequate drinking water; the down side of increased water consumption potentially causes damp litter. Increase in litter moisture has been reported when male turkeys were fed pellet, (Roberson, 2003). This was due to an increase in water consumption that corresponded to typically higher feed intake when pellet are fed. Litter dampness apparently creates an environment that can harbor large number of harmful parasites and coccidia (Roberson, 2003). In warm climates it is capable of giving rise to the development of large number of flies therefore in this respect the use of pellet can be said to be harmful, (Calet (1965).

The rapid growth rate resulting from feeding pellet may be a contributing factor to metabolic diseases, and a consequential increase in mortality due to ascites and tibial dyschondroplasia especially in male birds (Havenstein et al., 1994). These conditions result in economic losses due to reduced animal performance, which is an increasing concern for the broiler industry. Ascites caused by valvular insufficiency and right ventricular failure (RVF) following right ventricular dilation and hypertrophy from pulmonary hypertension (PH) has become a prominent cause of illness, mortalities, and condemnation in meat-type chickens, (Julian, 1998). The anatomy and physiology of the avian respiratory system in the fast growing broiler makes the bird susceptibility to pulmonary hypertension. In particular the small stature of the modern broiler bird, the large, heavy breast mass, the pressure from abdominal contents on air sacs, and the small lung volume may all be involved in the increased incidence of that malady, (Julian, 1998).

By and large, the bird's cardiovascular system can normally accommodate extra oxygen demands. When there is an increased demand for oxygen as a result of rapid growth, the heart pumps blood harder through the lungs to increase the amount of oxygen available for the bird's metabolism. Since the lung volume and cardiovascular volume within the lung tissue is fixed, there comes a point when the lung can no longer accommodate any more blood being supplied by the heart therefore the heart begins to fail causing fluid to accumulate in the abdominal cavity**,** Bennett et al. (2002) fed a mash supplement to reduce growth rate and reported that compared to a pelleted supplement, feeding a mash diet containing either wheat or barley supplement reduced mortality due to ascites and right heart failure (Nir et al., 1995) had also previous reported that feeding pellet increases mortality due to ascites. A number of other factors include temperature housing environment, rapid growth rates, high basal metabolic rate, high energy rations, high feed intake and feed form have also been known to influence the occurrence of ascites in broilers.

It is generally accepted that a major factor affecting broiler health and welfare is the issue of leg problems, which inhibit growth and render the bird incapacitated leading to death. The feeding of pellet has been known to be connected with the occurrence of skeletal and leg problems in the broiler bird. The broiler bird puts on muscle (meat) at a faster rate, than the supporting structure of legs, causing the birds to have difficulty in walking. Birds fed with the coarsely ground mash had the lowest mortality, whereas the highest mortality was found in the group fed the finely ground pelleted diet, (Engberg et al., 2004) **s**uggesting that mortality increases with faster growth rate following pellet feeding, which is often due to a higher frequency of ascites and leg disorders.

THE EFFECT OF FEED FORM ON INTESTINAL MICROFLORA

The dominating culturable bacteria in the small intestine of poultry are lactic acid-producing bacteria, in particular lactobacilli (Engberg et al., 2002). Since nutrient absorption mainly takes place in the small intestine, the numbers and type of activity of bacteria in this location is very important. These bacteria are usually considered to offer health benefits for the host, for example, prevention of diarrhea which is caused by gram-negative pathogens such as *Escherichia coli* and *Salmonella typhimurium* one of the most frequently isolated strains in human salmonellosis worldwide.

Differences in intestinal micro floral population can be influenced by feed form and particle size for example mash feed has been reported to lower the numbers of nitrobacteria, coliform bacteria in the ileum and increase numbers of lactobacilli in the small intestine and throughout the gastrointestinal tract, (Engberg et al., 2002). Additionally mash feed slightly improved the population of *C. perfringens* in the small intestine but significantly ($P < 0{\cdot}05$) increase the population in the ceca and rectum (Engberg et al., 2002) of poultry. The concentration of observed volatile fatty acid (VFA) due to microbial fermentation was lower in the ceca (Engberg et al., 2002) of mash fed birds than pellet-fed birds while Huang et al. (2006) reported that broilers receiving the pellet diet had a higher concentrations of total volatile fatty acids (VFA) in contents from both the gizzards and the ceca. The high concentration of VFA may be a result of fermentation products of microbes.

Feeding pellet has also increased ATP levels, (Engberg et al., 2002) in the gizzard and lower the pH of cecal contents due to improved cecal fermentation, which may be explained by the smaller size of feed particles present in pellet, (Calet, 1965). The authors suggested that the granulation process of pelleting may further expose the feed particles to degradation in the upper digestive tract. Similarly the cooking effect of the pelleting process improves nutrient availability and gives a significant reduction in microbial contamination (Ross, 2002).

The nutrients from those feed particles that enter the caeca are easily available for microbial fermentation. The low growth of lactobacilli and *C. perfringens* from pellet feeding was probably because of a reduced amount of undigested food remaining after digestion throughout in the intestine (Engberg et al., 2002). In this respect the feeding of a coarsely ground mash may have an advantage, since this feeding method stimulates gastric functions, including secretion of hydrochloric acid which decreased gastric PH concentration, and simultaneously increases the retention time of feed in the proventriculus and gizzard (Engberg et al., 2002). An increase in the number of coliform bacteria as an indicator of potential pathogens was observed in the ileum of pellet fed birds.

THE EFFECT OF FEED FORM ON BIRD ANATOMY

The structure of feed for broiler may have a strong influence on the anatomical and physiological functions of the digestive tract especially the gizzard. While there is limited work on the fate of pellet in the gastro intestinal tract, yet some studies have been conducted to validate the effect of pellet content. The development of the gastro intestinal tract and especially the gizzard is strongly influenced by feed particle size and consequently may affect nutrient digestibility. Feeding of coarsely ground feed or whole triticale has been found to significantly influence on the proventriculus and gizzard. (Jones, 2001), reported that the incorporation of whole wheat in a pellet resulted in significantly (P<0·01) greater gizzard weight (g/kg BW) than birds fed pellet containing fine-grounded wheat. However the size of the gizzard was greater in 42d old broiler than those in the starter phase.

On the contrary, feeding whole rather than ground triticale decreased the proventriculus size. Although, Jones, (2001) reported no differences in the proportional proventricular weights of the birds, the numbers of birds exhibiting proventricular dilatation indicated that feeding the ground wheat diets led to a greater (P=0·001) incidence of that condition than feeding the whole-wheat diets. The lack of development of the gizzard, a result of feeding diets containing ground grain, may lead to the onset of proventricular hypertrophy and dilatation.

The importance of these findings is that the more developed gizzard may be responsible for an increase in feed digestion and allow greater intestinal chyme thereby improving digestion of the grain by the bird (Jones, 2001). Improvement in apparent metabolizable energy content and food efficiency observed with whole wheat feeding instead of grounded wheat has been linked to more extensive grinding of food within the gizzard (Preston et al., 2000). This is in agreement with earlier findings by Nir et al. (1994) who affirmed that nutrient digestibility decreases when small particles are used because they cause gizzard atrophy. These observations are different from those made by Huang et al. (2006) who reported that birds fed a pelleted diet had significantly decreased relative gizzard weights, which is probably due to the lack of stronger mechanical stimulation by feed. The Ceca from pellet-fed birds, was observed to be significantly heavier than those from mash-fed broilers (Huang et al., 2006) that was probably due to increase activity of the ceca. Pelleting a diets to a large extent can reduce particle size, (Engberg et al., 2002); therefore increasing the amount of starch and other nutrients from the pellet diet that enters the cecum where they are easily available for microbial fermentation.

PARTICLE SIZE AND GRAIN TYPE

Nutrient digestibility from a pelleted diet is dependent on the size of particles contained in the pellet. For instance, Peron et al. (2005) studied the effect of particle size either coarse or fine ground particles on the digestibility of starch in a pelleted wheat diet. They observed that fine ground pellet significantly improved starch digestibility over course ground pellet. However, although fine grinding did not result in starch digestibility values close to 100%, the positive effect of fine grinding on wheat starch digestibility is in agreement with the assumption that a combination of particle size reduction and gelatinization may expose feed particles more efficiently to further enzymatic degradation, (Calet, 1965).

Birds are able to discriminate between food sources and when offered a choice between different feeds can select a mixture of the major nutrients, such as energy and protein that is broadly appropriate for their individual needs. True choice feeding, where the birds can select from separate food sources, is rarely used commercially, partly because of the cost of having to provide separate feeding systems. Studies in the literature indicate that if provided a free choice diet with equal portions of pellet and fines, the birds will consume the pellet first, (Kilburn, 2004). The general mindset is that birds prefer feed with larger particle size. Jones (2001) fed pelleted diets, incorporating whole or ground triticale or wheat in the pellet, to broiler chickens. He observed that the birds given ground wheat in the starter phase showed an improvement in food conversion efficiency compared to those birds offered diets whole wheat.

Effect of feed form on broiler performance can also depend on the type of grain use in the diet for instance Bennett et al. (2002) reported that although wheat or barley mash supplements had no significant effect on cumulative feed: gain ratio, wheat mash supplements increased feed: gain ratio only slightly. The youngest birds to exhibit a decreased growth rate were broilers fed 20% whole wheat and a pelleted supplement at 6 to 13 d. Birds fed mash or barley-based supplements were not affected by 20% whole grain this suggests better performance from barley than wheat since barley did not decrease growth rate.

Yo, et al. (1997) offered corn (either ground, cracked, or presented as whole grains) and a protein concentrate (43.7% CP) in mash or pellet form to broilers from 2 to 6 weeks old. When the protein concentrate was presented as pellet it induced a higher feed intake (40.1 g/d) than mash concentrate (33.4 g/d). However, offering corn as whole grains or concentrate, as pellet induced a significant improvement in feed efficiency when compared to mash. Based on the levels of intake, it can be they observed that corn was more acceptable when presented in ground or cracked forms than as whole grains, whereas a pelleted concentrate was more acceptable than a mash concentrate suggesting that the feed intake can vary depending of the physical form of the particles. Barley mash supplements had no effect on cumulative feed: gain ratio however wheat mash supplement increased feed: gain ratio only slightly, (Bennett, 2002).

Younger chicks in the starter (5 to 21 d) phase don't seem to respond favorably to pelleted diets. The absence of a positive effect of pellet at a young age seems in part due to particle size and birds anatomical development at that age. The ability of the digestive tract to quickly digest food has been reported (Rose and Kyriazakis, 1991; Jones, 2001). Younger chicks have a relatively small gizzard that is unable to quickly grind the whole-grain as a result they initially prefer the ground diet. However, as gizzard and remainder of the gastro-intestinal size increases due to age or continued exposure to whole-grain cereal or large particle size, these diets would be preferred. That behavior is evident by the increase and speed of feed consumption, at an older age. The improvement in performance is a sign that after the digestive tract had developed and adapted to the feed, the birds may have undergone a period of compensatory growth in the grower phase.

EFFECT OF FEED FORM ON BROILER NUTRITIONAL NEEDS

Broiler chickens grow extremely rapidly and are able to quadruple their birth weight within the first week of life. To achieve this, it is important that broiler diets have adequate levels of the necessary nutrients for growth and other metabolic requirements. Several techniques both nutritive and non-nutritive methods have been investigated to increase the availability of nutrients from broiler diets. Pellets go through a granulation process, which compact the feed ingredients together to increases, the bulk density of feed. In their study, authors Yo et al. (1997) concluded that when protein concentrate was fed as pellet, the proportion of concentrate in the selected diet was 33.0% but when presented as a mash, it contained only 29.6% of the concentrate. Similarly when corn was presented as whole grain, the percentage of concentrate in the diet was higher (35.1) than for cracked (29.4) or ground corn (29.5), which did not differ from each others.

The role of phosphorus in broiler nutrition has received a great deal of attention, and continues to do so, especially in the context of pollution from phosphorus run-off from agricultural operations, (Kilburn, 2001). For the fast growing broiler bird, nutritionally it is critical that the optimum amount of calcium and phosphorus be available at cellular level for metabolism. An important aspect of phosphorus nutrition is digestibility of phytate phosphorus. A review of the literature shows that presenting a diet in a mash or pellet form can impact the level of blood metabolites. There is practically no evidence that would indicate that pelleting diet would increase the availability of the natural phytate phosphorus in the diet to broilers.

The effect of pelleting on the digestibility of phytate phosphorus and calcium has been studied with different results. Kilburn (2001) investigated the individual and interactive effect of maize particle size, pelleting, phosphorus concentration, and 1, 25-(OH) 2 cholecalciferol on the nutrient utilization of broiler chickens. There was a significant interaction between feed form and maize particle size particularly in the utilization of phytate phosphorus. When in mash form, the diet containing the coarse maize resulted in an increased plasma phosphorus levels but when the diet was pelleted this trend was reversed as plasma phosphorus levels, were slightly lower for the pelleted diets containing coarse maize (Kilburn, 2001). This was evident by a substantial reduction in bone ash in broiler chicks. The authors also assert that pelleting changes the consistency and conformation of the food that could greatly reduce this partitioning effect thus the reason for the interaction. The findings were different from that of, Edwards et al. (1999) who studied effects of steam pelleting and extrusion of feed on phytate phosphorus utilization in broiler chickens and concluded that steam pelleting had no significant effect on the utilization of natural phytate by the chickens. When the diets were in mash form, the maize of larger particle size appeared to improve the calcium retention; however, when the diets were pelleted and crumbled, there was little advantage in feeding the larger particle size, (Kilburn, 2001). The above observation indicates that pellet improve calcium but not phytate phosphorus. Whereas the benefits of feeding pelleted diets over mash diets are well-documented and readily accepted by the commercial poultry industry, there is limited information in the literature concerning the effect of pelleting on dietary amino acid for broilers needs. Much of the research concerning the amino acid needs associated with feed form for growing broilers has been conducted using mash diets.

Dietary lysine concentration should be increased in pelleted diets in order for pellet-fed birds to achieve the same intake of lysine per g of body weight as mash-fed birds. In a recent study, Greenwood et al. (2004) evaluated feed form effects on digestible lysine and dietary energy utilization necessary for maximum growth performance of male broilers from 14 to 30 d. Birds were fed either mash or pellet containing graded digestible dietary lysine levels of 0.85, 0.95 and 1.05% and either 3050 or 3200 kcal ME/kg. Significant (P=0.01) feed form by digestible lysine interaction for body weight gain (BWG) was reported in that pellet-fed birds exhibited a significant (P=0.01) linear increase in BWG with increasing lysine concentrations. Maximum BWG was achieved with a highest lysine concentration for the pellet fed birds while mash-fed birds did not have improved growth response at digestible lysine levels greater than 0.85%. In terms of performance, birds fed pelleted diets also had a significantly (P=0.0061) lower lysine conversion ratio (digestible lysine intake: unit of body weight gain) than birds fed mash diets, as noted by the pellet fed birds consuming less digestible lysine to achieve the same amount of body weight gain as the mash-fed birds. McKinney (2005) reported that broilers that were provided pellet consumed more ($P < 0.05$) feed, lysine, and energy compared to those fed mash containing soybean oil (187 kcal MEn / kg diet).

Although Greenwood et al. (2004) and McKinney (2005) observed no significant interaction between feed form and dietary energy on both weight yet suggests that pelleting a diet potentially provides more energy for weight gain (via reduced activity energy expenditure), thus increasing the efficiency of lysine utilization, as well as increasing the lysine needs for tissue accretion (Greenwood et al., 2004). Additionally the findings indicate that feed form should be considered as a factor affecting the response of birds to dietary amino acid or energy levels, thus influencing the apparent nutrient needs of the bird.

PELLET AND FEED EFFICIENCY

Feed accounts for about 60 to 70% of the cost of production, which is the greatest cost of raising broilers and most livestock. Though it is not strictly a dietary issue, feed wastage results in the loss of important nutrients before the animals can ingest them. Feed wastage will reduce profitability; hence improving the efficiency of feed utilization will have a positive impact on the cost of production (Goodband et al, 2002). Feed waste is strongly influenced by the presentation of the feed for instance mash or fine feed tends to cling to chin of pigs and beaks of poultry ultimately and is a leading cause of ulceration and feed wastage. Pelleting the feed reduces feed waste on the farm and this is due partially to the bird's anatomy.

Since birds have no teeth they cannot easily grasp food consequently feed with uneven particle size have higher wastage because the smaller particles easily fall from the bird's mouth. As pellet are bigger they can be easily be picked up by the bird however pellet or food particles which are greater than 4-5 mm are both harmful to the chicks and are difficult for the young chicks to pick up (Calet, 1965).

Seemingly, a well-documented characteristic of pellet is its effect on feed efficiency. Plavnik et al. (1997) reported moderate improvement in feed efficiency only when feeding actual pellet to both 4- to 7wk old broilers and 8 to 20-wk-old turkeys regardless of age. However when grounded pellet were fed, it completely abolished the growth and feed efficiency responses observed when the intact pellet was fed. Jensen (2000) reported that past research has suggested a 10% increase in fines would increase feed conversion by approximately one point. When compared to mash the performance of birds fed the reground pellet was either not different or inferior to that of the mash.

In a related study unpublished data from Mc Kinney (2005), collected at the OSU research laboratory showed similar efficiency results with pellet vs. mash. In their study graded levels of pellet and pellet fines were fed to female broilers up to day 50. The diets contained 0%, 20%, 40%, 60%, and 80% pellet with the remainder being fines. Proportions of pellet and fines were blended to obtain desired levels of feed pellet. Linear increases were observed for weight gain, feed intake, and efficiency of gain. Birds with the highest percentage of pellet (80%) in their diet had an increased rate of gain and feed intake, and a decreased feed: gain compared to 0% pellet and mash indicating improved efficiency could be attributed to an intact pellet.

Although growth promotion separately may be adequate to clarify improvement in feed efficiency by pelleting, there are other effects of pelleting that have been considered in this respect. The question of activity is a mitigating factor in bird performance in that increase activity can affect performance.

In terms of activity, pellet and mash induce a profound adjustment of the feeding behavior in that broilers don’t spend equal time at the feed trough consuming either pellet or mash. The mean duration of the feeding bouts reported by Yo, et al. (1997) was two times shorter for pelleted concentrate (56 s) than for mash concentrate (114 s). Also chickens ate pellet at a significantly slower rate (number of pecks per second feeding time) than when eating mash concentrate. Similar reports were made earlier, when video observation of laying hens for 14 consecutive hours showed that mash-fed hens ate for longer periods than pellet-fed hens during the first 11 h (proportion of time spent eating:

41.3% to 32.5% mash and 20% to 25% for all the pelleted diets (Vilarino et al., 1996). Besides spending less time at the feed trough pellet fed birds spends more time resting (62.48 vs. 47.35%) than those fed mash (Skinner-Noble et al., 2005). The increase rest saves energy, which can be used for growth. The fact that the broiler bird is able to consume pellet faster and rest more will allow them to divert more energy for growth. One of the disadvantages of the increase rest is that pellet-fed birds are fatter than mash-fed birds. In recent years there has been a lot of concern about excess fat deposition in broilers. It is undesirable for both consumers and producer's point of view since consumption of excess fat has been implicated in a number of health problems

FEED FORM AND ENERGY METABOLISM

An accurate prediction of energy intake is important for ration formulation and in making economic decisions. Different approaches have been attempted to minimize energy loss and increase the energy available to the bird. As we have already discussed, broilers fed pellet, spend less time at the feed trough and those fed mash spend more time at the feed trough to consume food. It may seem obvious that this behavioral pattern cannot be energy efficient as it decreases feed conversion because more energy is expended to feed and other activities, which the bird could otherwise save by resting.

An estimate of the energy saving by the bird from consuming pellet has recently been evaluated by McKinney and Teeter (2004) who suggested that pelleting could increase effective caloric value (ECV) of the diet. The effective caloric value (ECV) is best defined as dietary caloric density (CD) necessary for broilers to achieve specific body weight (BW) and feed conversion ratio (FCR) combinations under standardized conditions (McKinney and Teeter, 2004). They reported that the energy saving accredited to pelleting alone peaked at 187 kcal MEn/kg feed consumed when birds consumed 100% PQ (the pellet to pellet fines ratio in the feeder). As the percentage of pellet increases from 20% to 100%, the apparent ECV of the diet became greater. The estimated energy sparing values diminished as the proportion of pellet to fines decreased, but still appeared greater than zero for the 20% pellet (76 kcal MEn/kg diet McKinney and Teeter (2004). A noticeable advantage of pellet has been confirmed by Choi et al.(1986); Calet (1965), who reported that compared to mash feeding pellet increased feed intake, which improved the broiler growth rate. While Petterson et al. (1991) reported that dry pelleting improved feed conversion ratios by about 7% and feed intake by about 16%.

Because broilers consume pellet faster than mash, and had more time for resting (62.48 vs. 47.35%) from pellet and mash respectively (Skinner-Noble et al., 2005), the increased rest ($P<0.05$) presumably was the cause for increased ECV for pellet compared to mash.

Most of the data to date indicate that pellet improve bird performance. Poorly manufactured feed with excess fines results in some of the birds consuming only pellet first, leaving the smaller fines for less aggressive birds. Because pellet quality affects the rate of growth, the presence of excess fines in a feed can affect flock uniformity, which can cause the stronger birds to consume more pellet. In fact when used in a regression model, the interactive effects of eating and resting efficiently model ECV, with an R^2 of over 99% (Skinner-Noble et al., 2005). Neither eating nor resting alone was enough to have an effective ECV response. Although the report detailed no significant ($P = 0.0679$) differences between the feed forms for NEg/kg, numerically (2,351 for pellet vs. 2,107 for mash) bird NEg/kg response from pellet seems to lend credit to the argument that pelleting increased dietary energy available for gain by increasing resting and decreasing eating behavior (Skinner-Noble et al., 2005). This premise agrees well with Preston et al. (2000) that ME: gain ratio of the mash diet was significantly greater (P <0·001) than for any of other feed forms and that the pelleting process increased the metabolizable energy content of the diets (Kilburn and Edwards, 2001).

An explanation of energy response to pellet has been given by McKinney and Teeter (2004) who proposed that as pellet quality increases, either the bird expends less energy for consumption or the bioavailability of nutrients or energy increases. Additionally the increase in resting and decrease in eating appears to be the driving factor leading to a 10-point improvement in FCR during the finisher phase. Therefore a greater proportion of pellet in a diet should reduce energy expenditure during consumption, thus resulting in an increased retained energy (Greenwood et al., 2004).

LIGHT

Light is an important aspect of an animal’s environment. In the past light was not was not used as a management tool in poultry operations on a daily or weekly basis. As an alternative, for many years, it has been assumed that rearing broiler chicks under nearly continuous from 23 to 24 hours a day lighting conditions would give a maximal growth rate due to higher feed consumption. However, over the past three decades extensive research has been conducted dealing with the effects of different lighting schemes on broiler performance and body structure Ingram and Hatten (2000). During that period light has become a component of the poultry environment that is regulated as the bird grows. Most of the research in light treatment has focused on intermittent lighting schedules, consisting of short light/dark cycles, other aspects of light that have been studied include light intensity and color of light and source of light.

The broiler producer must consider several critical factors in the design of a lighting program in doing so housing type is the first concern. In the United States, both dark and light colored curtains are common in broiler production facilities. However, clear curtained sidewall housing prevails in most of the rest of the world (Olanrewaju et al., 2006). Broiler producers with clear curtains and/or open sidewall houses are restricted in lighting alternatives and are forced to design lighting programs around the limitations of natural daylight/length. Houses with dark curtains or solid sidewalls allow the producer to establish lighting systems that control intensity, duration, and wavelength throughout the entire grow-out period (Olanrewaju et al., 2006).

The use of intermittent lighting in broilers and in turkey reproduction has both biological and non-biological benefits. The biological benefits will be discussed later however the non-biological benefits are of economic importance and may result from substantial savings in the electric costs due to lighting.

SOURCE OF LIGHT

Different light sources are available for use in the poultry house most of which give similar results. Incandescent light bulbs are sometimes used and are less expensive, easy to install and very efficient on electricity, fluorescent bulbs are more costly to install but they are more efficient than incandescent bulbs. Neon lights are more efficient than those mentioned thus far however the light intensity is more difficult to control. Skinner, and Sunde 1990. Incandescent or fluorescent fixtures are the most common in poultry facilities.

LIGHTING PROGRAMS

For poultry, light can be used to facilitate sight, maximize the production of hatch able eggs, limit food intake, molting, stimulate internal cycles due to day-length changes, and to initiate hormone release among others. For some type of production birds, a common farm practice is to use lighting schedules to control early growth rate to allow time for the internal organs and the skeleton to develop before too much muscle is laid down.

The objective of broiler breeders is to have the birds to consume an “ideal” amount of nutrients within a given time period to produce a bird whose weight, body condition and frame allow the reproductive organs to mature and function at their best Tabler and Bramwell (2003). Since withholding light is a good form of feed constraint, lighting programs applied during certain critical periods in the growth curve can modify early growth and later enhance compensatory gain. Sorensen et, al. (1999) reported some compensatory growth as illustrated by daily gain from 28 to 35 d of age. This gain was 71.3 g on a 16 h photoperiod treatment but 68.3 g on the 21 h photoperiod treatment. However reducing day length too early will reduce feeding activity and depress 7-day live weight Broiler Management Manual (2002).

There are a wide variety of lighting programs and devices with their own characteristics and applicability that is available to poultry producers. Example, for the broiler breeder, after the first few days of life they are usually provided with a short dark period of .5–1 h each day to allow them to become accustomed to darkness in the event of power failure Broiler Management Manual (2002). The broiler breeder bird generally receives restricted light for the first 20 weeks of life. From 22d-20weeks light is restricted to 8L: 16D then from 20-21 wks 15L: 9D and than from 21 to end of the laying cycle 16L: 8D. Lighting later than 20-22 weeks allows females to become larger and more mature at the onset of production. Unfortunately, lighting birds later will likely also delay egg production until 25-26 weeks Tabler and Bramwell (2003). For laying birds, baby chicks are provided with 16 to 24 hours light for the first 2 to 3 days so that the bird can find food and water. During the growing period, hours of light are gradually reduced until natural daylight length is achieved. Other lighting programs 12L: 12D (12 hr light: 12 hr dark) and 23L: 1D (23 hr light: 1 hr dark) have been investigated for application to broiler bird with some success. The role of light restriction is critical and if applied wrongly can actually negatively impact performance.

THE EFFECT OF LIGHT ON BROILER PHYSIOLOGY

When light energy passes through the skull it stimulates photoreceptors in the hypothalamus to release luteinizing hormone releasing hormone (LHRH), which stimulate the anterior pituitary to produce and release follicle stimulating hormone (FSH) and luteinizing hormone (LH) (Robinson and Renema, 1999). These hormones act on the ovaries or testes to stimulate follicle and sperm production, respectively. In the ovary, the small follicles produce androgens and estrogens that stimulate development of secondary sexual characteristics, oviduct development and enlargement to secrete albumen and mobilization of calcium from bone are some of the other responses (Robinson and Renema, 1999)

LIGHT INTENSITY AND DURATION ON BROILER PERFORMANCE

The benefits of broiler lighting programs on improved performance as measured by improved livability, average daily gain (ADG) and calorie conversion or feed conversion rate (FCR) has already been established (Beker.2006; Classen et al., 1991; Buyse et al., 1994). Yet a review of the literature seems to suggest that the role of light restriction in the management of broiler production is still yet to be determined. Most of the work that has been done so far, suggests that broilers reared under restricted and intermittent light are heavier at the time they reach market age than those on continuous light. The response to intermittent and restricted light is not the same throughout the growth curve. In fact body weight gained under different lighting programs has been determined to be related to the age and sex of the bird. Rozenboim et al. (1999) reported that by 42 d of age, photoperiod had no effect on growth. But at 49d old broilers reared under restricted light of 16L: 8D regimen were heavier than those under 23L: 1D. These results are not in agreement with Ingram et al.(2000) who earlier confirmed that increased period of darkness 12L:12D applied to broilers in the starter, grower and finisher stages caused an overall decrease in feed intake of 4% and significantly decreased body weight of 2%, when compared to 23L:1D. The differences in the results of those two studies could be due to bird age because the 12L: 12D light restriction was limited to only 42d while the 16L: 8D lasted until 49D.

A report of the Scientific Committee on Animal Health and Animal Welfare stated that a move from 24 h to 12 h light at 4 days of age will reduce food intake by 30-40% for the first 3 days, but this reduction is <10% by day 12. The author speculates that this ability improves their food consumption and FCR at later ages. In 12L:12D lighting programs broilers also benefit from a clear pattern of day and night by having distinct periods of rest and more vigorous periods of activity.

While intermittent restricted lighting programs may have the same or longer periods of darkness overall as the non-intermittent restricted programs, the intermittent programs show body weight gain and the non-intermittent programs show body weight loss (Ingram et al., 2000). It is for this reason Al-Homidan (2001) reported significantly (P<0·01) greater mean body weight and daily weight gain at 7wk when Hybro broiler birds were reared under intermittent light (3L :1D) than those under near-continuous light (23L : 1D) or intermittent light (5L : 1D). Similarly, body weight of White Leghorn pullets on the step-down light regimen that is those which were exposed to 23l: 1D at day-old and was gradually reduced to 8 h/d at 15 wk of age were significantly ($P < 0.05$) heavier (173 vs. 126 g) than the pullets of the short-day light regimen (which were exposed to 8 h/d light during the growing period) during most parts of the growing and laying periods (Keshavarz, 1998).

Along with duration of light the issue of light intensity has been considered for application in the hen house. The intensity of light required by the bird changes with age and is related to activity. Davis et al. (1999) reported that if give a choice, 2 weeks old broiler and layer strains of fowl seem to spend most of their time in light intensity of 200 lux environment while older birds at 6 weeks preferred dimmest lights of 6 lux. The preference of the different intensities was related to the type of bird activity. The apparent change in preference was associated only with the two behaviors that took up most time, resting and perching in dim light, whereas the highest intensity was consistently preferred for all other behaviors. Older birds thus preferred to be in dim light when they were relatively inactive (Davis et al., 1999). The brighter lighting is important to stimulate activity, which may be essential for survival in the first week of life. Therefore in the commercial broiler production, it is common to use intensities of 20-lux minimum until 7 days of age. Continuous lighting at around 20 lux will ensure that chicks acclimate properly to their environment, as indicated by optimal feed and water intakes. Following the early period, restriction of both light intensity and duration is usually implemented then gradual reduction from 20 to 10 lux between 7 and 21 days, and 6-10 lux thereafter (Ross Breeders, 1996). Alternatively, intensity can be kept at 15-20 lux throughout the growing period. For meat birds, it is common for intensity to be from 3 to 5 lx and duration from 2 to 6 h/d for the remainder of the grow-out period (Olanrewaju et al., 2006).

COLOR OF LIGHT ON BROILER PERFORMANCE

Color is an important aspect of light that has been considered at one time as a management tool in poultry production. Prayiotno et al. (1997a) observed a Ross strain of broiler that was reared in red, blue, green and white color light. In that study bird behavior was above all affected, but not growth rate while in another study, Prayiotno et al. (1997b) growth rate was significantly impacted. For the most part birds exposed to red and white light are more active, in that walking, standing, drinking, aggression, and wing stretching increased with intensity in red light but not blue light. Also the superior activity seems to have resulted in greater sleep in these birds, meanwhile the birds in the green and blue lights spent relatively more time sitting or dozing. The authors concluded that the inability of increased intensities of blue light to increase standing and walking suggests the sensitivity of long wavelength light by the pineal gland is essential to the effect on activity. The directional collective response of increased feeding time in green and blue light for male birds and white light for the female birds, also heavier bone along with a filled crop and gizzard content in the green and blue light does not affect growth at the end of the grower phase. It appears that when light is offered for an extended period to the finisher phase, the effect of red light relative to growth is realized. Providing red light early increased final body weight but providing it later decreases body weight and average bone weight (Prayiotno et al., 1997b). Blue or green light is preferable to red or white light for broilers because it keeps the birds calmer and is chosen by the birds themselves (Prayiotno et al.,1997a).

Leg weakness is a vague term used to describe a series of debilitating conditions, of infectious and noninfectious origin, that affect modern fast-growing strains of broiler chickens (Sorensen et al., 1999). These abnormalities are sometimes manifested by an unsteady gait that gives the impression that the bird is struggling to walk. Additionally the birds look like they suffer from pain when they walk which may hinder their ability to reach feed and water ultimately impacting performance. Offering dim blue light to broiler from 7D to 55D has resulted in a high incidence of gait abnormalities however offering bright red light either throughout the starter phase or from 22 D to 38D reduced the abnormalities. The reason, is rearing broiler chickens in bright red light supposedly increases activity, which reduces locomotion disorders in the late rearing period while blue light does the opposite**.** The failure of blue light to increase standing and walking suggests that the observation of long wavelength light by the pineal gland is important for activity (Prayiotno et al., 1997b). It may be possible in the long run to use light stimulation to reduce the incidence of leg disorders in meat chickens.

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CHAPTER III

Quantifying additively between lighting schedule and feed form on broiler metabolic efficiency.

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INTRODUCTION

Prior to the mid 1990's the vast majority of broiler producers reared birds under near continuous lighting exposure so that body weight might be optimized through feed availability. Such an approach ignores energy expenditure for activity. Indeed, bird activity has been shown to impact energy utilization as resting birds exhibit minimal amounts of heat loss while standing, feeding and social behavior increase heat loss (MacLeod, 2000). Work conducted in our laboratory by Beker and Teeter, (2003) suggests that as much as 19% of bird metabolizable energy intake is used for activity Balnave (1974) reported that the heat production from activity of fed birds in the standing position was approximately 42% higher than in the sitting position. McKinney and Teeter (2004) demonstrated a relationship between increased resting behavior which can be associated with pellet and increased ECV of the diet.

Lighting programs application as light duration is a well-established practice that has been used by the poultry industry. Indeed, lighting studies and programs have been highlighted (Cobb Vantress, 2003) to enhance broiler production efficiency. However, the precise metabolic effects of lighting program on broiler metabolism as energy expenditure and tissue accretion efficiency is moot. Of the many different lighting programs being implemented, most of them have been reported to have variable degrees of success for example Ingram et al. (2000) and Al-Homidan (2001) reported higher body weight gain when broilers were offered intermittent programs compared to non-intermittent lighting programs while Ingram and Hatten (2000) suggested that light restriction resulted in lower body weight.

Since bird activity is reduced in the dark, (Ohtani and Leeson, 2000), lighting programs were considered to control activity. Consequently the traditional belief that continuous or nearly continuous lighting (23L:1D) duration optimizes poultry performance (Ingram and Hatten, 2000) was questioned. Beker (2006) observed that subjecting broilers to a 12L:12D lighting program increased feed intake, live weight gain, and efficiency of ME utilization for live mass accretion. The lighting treatment resulted in calorific savings of 104 Kcal/ kg of ration. However, studies by Ingram and Hatten (2000) suggested that light restriction resulted in lower body weight with improved feed conversion. The difference between the two trials could probably be influenced by bird age and breed as the Beker study utilized cobb x cobb broiler while Ingram no mention is made of the breed of broiler utilized. Light restriction may initially delay weight gain but with compensatory gain later in the growth curve.

Mc Kinney and Teeter (2004) quantified the calorific value of pellet quality as effective caloric value (ECV) the authors defined ECV as the dietary caloric density (CD) necessary for broilers to achieve specific BW and feed conversion ratio (FCR) combinations under standardized conditions. Their results indicated that pelleting broiler feeds has the potential to provide a calorific advantage equivalent to 187 Kcal ME/kg ration at 100% pellet quality, principally through activity energy saving. The common advantage of lighting and pelleting is that birds have more inactive time and therefore utilize less energy for activity (Lanson and Smith, 1955). In fact 38 to 45D old turkeys fed pellets spend 4.7% and 2.2% respectively of a 12-hour day eating pellets, compared to 14.3% and 18.8% for those fed mash (Jensen et al., 1962). Similarly, Skinner-Noble et al. (2005) reported that birds fed pellets were observed eating less often (4.25 vs. 18.81%) and resting more (62.48 vs. 47.35%) than those fed mash. The greater periods of rest may certainly contribute to caloric advantage. Indeed the authors reported a 151 kcal ECV enhancement.

The rising incidence of obesity and other health problems due to high cholesterol levels in the human diet has led to nutritional concerns to decrease both fat intake and consumption of saturated animal fats. There is interest in the poultry industry to reduce fat deposition in broiler carcasses to produce a leaner bird and reduce the unfavorable effects of fat on human health. This at least partially, explains the increase in the consumption of poultry products in place of red meat. Per capita domestic broiler consumption (retail weight basis) is expected to increase to nearly 88 pounds while beef consumption is about 67 pounds (USDA, 2006). Increased consumer demand for lean tissue, together with the rise in feed cost, has further elevated the need to improve lean tissue gain through improved husbandry practices. That increase demand has resulted in a decrease need for beef and no significant increase in the demand for pork. Additionally, lower poultry prices have lead to lower red meat demand (USDA, 2006).

Since the aforementioned light and pelleting studies were conducted independent of each other, further research is needed to ascertain if the two approaches function in an additive or interactive manner. The objective of this experiment was, therefore, to evaluate and quantify the interactive value of lighting and pelleting on body weight gain, feed consumption, feed efficiency, energy consumption, whole bird body composition, and energetic efficiency.

MATERIAL AND METHOD

Two hundred (200) male Cobb chicks (1-old) were obtained from a commercial hatchery, weighed, wing banded and placed randomly into four floor pens with fresh wood shavings. Brooders were set to provide adequate temperature. Chicks were given a starter diet containing 22.1% CP and 3,053 Kcal/kg ME. Both feed and water were provided for ad lib consumption throughout. When the birds reached 12 days of age chicks were transferred to metabolic chambers to be acclimatized for four days. Out of these, seventy-two (72) chicks of similar weights were retained and randomly redistributed at the rate of 3 birds per chamber.

Metabolic chambers

General characteristics of the plexiglas and metabolic chamber methodologies have been described previously (Belay and Teeter, 1993**;** Weirnusz and Teeter, 1993). However in this experiment, each chamber was individually fitted with a 75-watt incandescent bulb with voltage regulator to adjust light intensity to .5-foot candle. Light intensity was measured using a digital light meter Greenlee Textron Inc[1]

The Plexiglas top allowed the chicks inside the chamber exposed to varying light treatments during the measurements. The respiration chambers were situated in light-proof, temperature controlled room as described by Ohtani and Leeson (2000). Chambers were encased with a layer of black polythene plastic to prevent light from shining out or into the neighboring chambers. Chicks were fed either a mash or pellet and exposed to either 12L: 12D or 23L: 01D in a 2 X 2 factorial treatment arrangement. Mortality was recorded daily throughout the study while body weights were recorded on 35, 42 and 50 days. Feed consumption was recorded when feed was offered. Oxygen consumption and carbon dioxide production was determined 3 times per hour on days19, 20, 24, 25 and 30 so that heat production (HP) might be computed according to Brouwer (1965).

Feed

Typical grower (CP 19.8%; ME 3131 Kcal/kg), finisher (CP 17%; ME 3174 Kcal/kg) diets were offered in pellet or mash forms. Pellets were prepared from the same batch as the mash diet. Before feeding, pellets were sieved through 0.3 X 0.3cm sieve similar to the one described by McKinney and Teeter (2004) to remove fines.

On day 50, birds were euthanized using carbon dioxide inhalation prior to scanning with Hologic[2] X-ray densitometer. As a test of the X-ray densitometer results, the values of the adjusted bird protein, water, lipid, and ash were compared with the gravimetric weight. Body weight calculated from adjusted X-ray densitometer measurements not within ± 5% of the respective gravimetric weight were excluded and

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[1] Greenlee Textron Inc
[2] Hologic, Inc.
35 Crosby Drive, Bedford, MA 01730, USA

the accepted scans for each bird were combined for analysis as described by McKinney (2005). The related energy value of each treatment was utilized via the effective calorie value method ECV=3983.8 + 0.25857*wt50d-849.33275*cummfcr0to50 (McKinney and Teeter, 2004). ME efficiency for gain (metabolizable energy intake/weight gain) as energy efficiency were measured and recorded.

Statistical analysis

The experimental design used was a 2x2 split plot arrangement of treatments in a complete randomized block design with light as main plot and feed form as sub plots. Data were analyzed using GLM procedure of SAS (2000) with initial body weight incorporated as a covariate where appropriate. Where significant F statistic was detected, treatments were separated using least square means.

RESULTS AND DISCUSSION

Light and feed form effect 16-35 d

Results for days 16 to day 35 (grower phase) of the experiment for Bwt gain, feed consumption and feed efficiency are shown in Table 1. There were no significant interactions between light and feed form for body weight gain, and feed efficiency. Birds that were fed pellet and reared under nearly continuous lighting of (23L:1D) had greater body weight gain at 1706g than all other treatments averaging 1541g and consumed more feed 2502g versus other treatments averaging 2283g. These differences were at similar feed efficiency (FE). However the birds fed pellets in restricted light were the most efficient .70 compared to the other treatments averaging .67.

Results of the main effects of light and feed form are shown in Table 2. Averaged over feed form, birds reared under a restricted 12 hr light: 12 hr dark (12L: 12D) responded differently from those in the conventional 23L: 01D lighting program. The non-intermittent (12L: 12D) restricted lighting program restricted body weight gain. Similar effects on weight gain have been reported in earlier studies by Ingram and Hatten (2000). In contrast, Al-Homidan (2001) observed that male broilers reared in another type of restricted lighting (3L: 1D)] performed better than continuous lighting. Rahimi et al. (2005) reported lower body weight gains on broilers from 1-14 d of age under intermittent lighting of 1L: 3D. This suggests that when restricted lighting is offered to broilers from 16 to 35D, body weight gain may be restricted presumably due to insufficient light duration for the birds to eat. Under these conditions feeding pellets offer advantages for both gain extent and efficiency of gain.

Although the reasons for the performance differences to date are moot, data suggest that 23L:1D lighting for male broiler chicks 16 to 35 days is needed for birds to consume more ($p<.01$) feed (2439g vs. 2236g) and therefore gaining more ($p<.01$) weight (1648g vs. 1578g) compared to 12L:12D. Feed form was important but could not overcome lighting inadequacy for peak gain while feed efficiency was superior. Interaction suggest that results are interactive during 16-35d for feed consumption while other effects are additive.

There were no differences ($p< 73$) in feed efficiency between the light schedules for day 16-35 when the data were analyzed over lighting. These observations are in disagreement with Ingram and Hatten (2000) who found that 12L: 12D birds were more efficient than continuous lighting birds at that age. Possible reasons for the differences in results are that, in their trail the birds were reared from day old in wider pens that measured 1.52 X 3.05m with 1ft^2/bird which allowed for more movement and activity. In this experiment, the birds were caged from 16D in smaller metabolic chambers, with # ft^2 a situation atypical of commercial growing conditions that allowed limited activity and may have compromised efficiency.

Consistent with other work is the improvement ($p<.01$) in weight gain by pellet-fed compared to mash-fed birds (1637 vs. 1529g) reported by numerous authors Engberg, 2002, Skinner-Noble et al., 2005, McKinney and Teeter, 2004, Plavnik et al., 1997 and Jensen et al., 1962. An increase in body weight from feeding pellet was also observed in turkeys (Roberson, 2003). In the reported study pellet-fed birds consumed more ($p <0.06$) feed compared to mash-fed birds (2372g vs. 2304g). Results resemble a pattern of broiler performance that is consistent with other studies (McKinney and Teeter, 2004; Choi et al., 1986) in that feed consumption is higher when broilers are fed pellets compared to mash.

Feed efficiency was estimated as body weight gain per gram of feed consumed. There was an improvement ($p<.01$) in efficiency of pellet-fed birds compared to mash (.69 vs. .66 respectively), which is in accordance with Greenwood et al. (2004). As discussed pelleting a feed may lead to an increased in food intake and efficiency of feed food utilization presumably due to dilution of maintenance cost. In considering a possible mode of action it is assumed that when pellet are fed broilers spent less energy for feeding and for other activity. This allows broilers more time for rest (McKinney and Teeter, 2004; Skinner-Noble et al., 2005) therefore making them more efficient (Greenwood et al., 2004). Another form of efficiency was expressed as kcal MEn intake per gram of live weight gain. Pellet fed birds were more efficient as they consumed less ($p<.01$) Kcal of metabolizable energy per gram of live weight gain than birds fed mash.

Light and feed form effect 35-42 d

Results of lighting schemes and feed form on broiler performance from 35 to 42D are displayed in (Table 3). There were no interaction between light and feed form for body weight gain ($p<0.22$), feed consumption ($p<0.133$), and feed efficiency ($p<0.26$), for that period consequently only the main effects (table 4) will be discussed.

Results of the main effects of light and feed form are shown in Table 4. Averaged over feed form, birds reared in 12L: 12D exhibited ($p<.01$) greater body weight gain (691 *vs.* 607g) than the birds in 23L:1D. This indicates that an older market age may provide opportunity to achieve an improved body weight as more time is allowed for compensatory gain. The 12L: 12D consumed similar amounts of feed ($p<0.43$; (1471 *vs.* 1448) and were more efficient ($p<0.01$; .47 vs. .42) than those reared in 23L: 1D. Since physical activity during the dark is presumed low then energy expenditure of activity is reduced. Reduction in physical activity with intermittent light has also been reported by Rahimi et al.(2005) to contribute to enhanced production efficiency when expressed as feed conversion rate (FCR) as 1.90 for birds in intermittent versus 2.03 for birds in continuous light. In terms of economics it would be better to use a 12L: 12D lighting program with pellets assuming that the cost of pelleting does not exceed the advantage.

The small improvement in feed intake by the birds in the 12L: 12D lighting may be related to adaptation of the lighting program that was offered. The earlier lighting restriction from the 12L: 12D lighting schedule lasted 19 days. Presumably during later periods, the birds would adjust their eating habits and increase feed intake to compensate. Increased intake allowed for a compensatory gain causing the birds on restricted light to gain more weight than those in continuous lighting, which was an improvement from the starter phase. It has been shown that, when an animal whose growth has been retarded by dietary restriction is given adequate nutrition, that animals grow at a faster rate than an animal of the same age that had no prior restriction. This phenomenon has been recognized as having the potential to have profound effects on the rate or growth and body composition of most animals (Tumova et al., 2002; Buyse, 1996; Sorensen et al., 1999; Lee and Lesson, 2001). In the broiler bird, early life feed restriction causes a shift in nutrient and energy supply, giving priority to the early maturing supply organs which are more important during early development and redirecting a proportion of the food normally designated for the more late maturing demand tissues (Govaerts et al., 2000).

During that phase, body weight gain (654 vs. 643) feed consumption (1480 vs. 1439) and feed efficiency (.44 vs. .45) were only numerically ($p>.10$), higher for pellets than mash. Improvement in body weight gain, feed consumption and efficiency in response to pellet compared to mash is well recognized.

Light and feed form effect 42-50 d finisher phase)

Broiler performance in relation to feed form in 12L:12D or 23L:1D for the finisher phase is shown in Table 5. There were no significant interaction between light by feed form during the 42D to 50D period of the finisher phase for body weight gain ($p < 0.96$) and feed consumption ($p < 0.95$), but there tended to be a interaction ($p<.08$) for feed efficiency. Consequently main effect of light and feed form on body weight gain and feed consumption will be discussed. Interactive effects of efficiency will be considered. Birds in both 23L:1dD and 12L:12D lighting schedule that were offered either pellet or mash had similar body weight gain which averaged 584 g. Offering mash or pellets to birds in 12L:12D resulted in an average feed consumption of 1281 g while offering mash or pellet to birds in 23L:1D resulted in an average feed consumption of 1257g. Offering either feed forms in 23L: 01D resulted in similar efficiencies however there was a tendency for birds in 23L: 01D that were fed mash diet to gain less and consume the less feed while the birds in the 12L:12D that were fed pellets to gain slightly more weight. Although not statistically different, the birds' in12L:12D that were fed pellet were numerically more efficient than all the other treatments while the birds in the 23L:1D that were fed pellet were numerically the most inefficient.

Results of the main effects of light and feed form are shown in Table 6. When the data was analyzed over feed form, the birds in the two lighting schedules performed similar for instance, broilers that were reared in 12L: 12D had a numerically ($p<0.36$) higher body weight gain (604 vs. 564g) compared to those in 23L: 01D. Feed consumption was not different ($p<0.63$) while there was a tendency ($p=.08$) for 12L:12D birds to be more efficient (.47 vs. .45) than 23L: 01D.

Averaging over light for that period, pellet-fed birds gained slightly more ($p<0.25$) weight (604 *vs.* 564g) respectively and consumed more ($p< 0.10$) feed (1317 *vs.* 1221) than the birds that were fed mash. Improvement in body weight in pellet-fed birds is in agreement with observations by Plavnik et al. (1997); Engberg (2002); Skinner-Noble et al. (2005), McKinney and Teeter (2004); Plavnik et al. (1997) and Jensen et al. (1962).

There were no differences in feed efficiency among pellet and mash fed birds. This suggests that from a practical point of view it is more economical to feed pellet during a 12L:12D lighting schedule to broilers on day 42-50 of the finisher period since the birds are slightly more efficient with that treatment combination providing that good management practices are optimized.

Light and feed form effect on cumulative 16-42 d

Overall cumulative results for day 16-42 period are represented in Table 7. There were no light by feed form interaction on cumulative weight gain. However there was tended to be interaction between light and feed form for feed consumption (p=.07) and efficiency (p=.09). The birds in the 12L:12D and 23L:1D that were fed pellet had similar mean body weight gain. While those in 12L:12D and 23L:1D lighting that consumed mash also had similar weight gain. This suggests that by 42D, the use of feed form was more important for body weight gain irrespective of the lighting schedule offered. The birds in 23L:1D that were fed pellets had only numerically superior body weight gain than the birds in 12L:12D that were fed pellet although those in 23L:1D had significantly greater body weight gain on 35D. Since weight gain for 12L:12D pellet and 23L:1D pellet were similar, suggests that the use of 12L:12D may contribute to improved weight gain at that stage. The birds' performance at that stage is a reflection of compensatory gain as described by Sorensen et al. (1999). The greatest (p<.01) feed consumption was 3990g and highest body weight gain was 2322g were among the birds that were reared in 23L:1D and fed pellet. Birds in the 12L:12D that were fed pellets were the most (p<.01) efficient .61 in converting feed to weight gain. A similar response on feed efficiency from 12L:12D consuming pellet was also observed earlier on 35D.

The results of the main effects of light and feed form are represented in Table 8. Averaged over feed form there were no differences in body weight gain due to the lighting program. Similar results have been reported by Rahimi et al. (2005) who observed no difference in body weight gain at 42d. In their study broilers were offered either continuous or intermittent lighting schedule that consisted of cycles of one hour light followed by three hours dark (1L:3D). The similar body weight gain attained at 42D is an indication of catch-up growth attained by the birds in 12L:12D which originally had significantly lower body weights gain by 35D. Offering continuous light allowed the birds time to consume more ($p<.01$) feed (3887g vs. 3708g) than restricted light**.** Lower feed consumption and similar body weight gain attained by the birds in 12L:12D resulted in better ($p<.01$) feed efficiency (.60 vs. .58) than birds in continuous light. Averaging over lighting schedules, pellet fed birds had a higher ($p<.01$) body weight gain (2291 vs. 2172g) and consumed more ($p<.01$) feed (3853 vs. 3743g), than mash fed birds. Broiler in 12L:12D were more ($p<.04$) efficient (.60 vs. .58) than the ones in 23L:1D which agrees with Beker, (2006)

Light and feed form effect on cumulative 16-50 d

Table 9 provides bird performance from 16-50D. There were no ($p < 0.49$) interactions between light and feed form on body weight gain however there was a significant interaction for feed consumption and cumulative feed efficiency.

Across the treatments, birds in 12L:12D lighting schedule that were fed pellets exhibited numerically more $p=.10$ weight (2897g vs.2813g) than the birds in 23L:1D that consumed pellet. Similarly, broilers in 23L:1D and 12L:12D that consumed mash also attained similar body weight gain (2702 vs. 2706g). This indicates that feed form was more important than lighting program for body weight gain. However along all the treatments the birds in restricted light that consumed pellet gained numerically the most weight 2897g and coupling this with similar feed consumption, they were the most (p<.01) efficient at .58. Feed consumption (5308g) was the highest (p< .01) when the birds were reared in continuous light and fed pellet. High feed consumption and lower body weight gain resulted in the birds in continuous lighting that consumed pellet to be numerically the most inefficient (.53) at feed conversion.

Table 10 represents the results of the main effects of light and feed form for the period 16 to 50D of the study. Altogether feed form had a greater impact on cumulative body weight gain than the lighting programs. Averaging over light, broilers that were fed pellet had a higher (p<.01) body weight gain (2855g vs. 2704) and consumed more (p<.01) feed (5171 vs. 4964g) but exhibited similar (p>.10) efficiency compared to those that were fed mash. The significantly higher body weight gain and feed consumption observed as a result of feeding pellet is consistent with Jahan et al. (2006) who reported that feeding mash to broiler chicks resulted in significantly (P<0.05) lower body weight gain than feeding pellet.

When averaged over feed form, there were no (p>.10) differences in body weight gain as a result of the lighting programs nevertheless the birds in 12L:12D had attained a numerically higher (p>0.77) body weight gain (2801 vs. 2758) than 23L:1D. Higher body weight with intermittent light has also been reported by Ohtani and Leeson (2000). The birds in 12L:12D however consumed less (p<.01) feed (4989 vs.5145) than the birds in 23L:1D which is not in agreement with Ohtani and Leeson (2000) who reported than the birds in 23L: 01D consumed less fed than birds in restricted light of 3L : 1D). Birds in 12L:12D lighted program had a better (p<.01) feed conversion efficiency (.56 vs. .54) than the ones that were offered continuous lighting. Despite the lower feed intake in broilers exposed to 12L:12D had their body weight gains and feed efficiency were comparable with those of broilers exposed to the usual continuous light per day, presumably, due to lower energy expenditure on physical activity Oyedeji and Atteh (2005). Although there were no significant differences in body weight gain between the two lighting programs, the results of this study seems to indicate that there was a potential for birds in 12L:12D lighting to attain higher body weight gain than the birds that are offered continuous lighting which are in agreement with Beker (2006) who observed higher weight gain with restricted lighting.

Body composition

Carcass characteristics of broilers at 50 D are represented in Table 11. There were no significant interaction between light and feed form on protein, fat, water, and ash gain at the end of the experiment on 50D. Among all the treatments, broilers in 12L:12D lighting scheme that consumed pellet numerically had the highest ($p<.12$) gain of protein 609g, fat 665g, ash 211g and body water 92g. Assuming that live weight gain is mostly the deposition of protein, fat or water it is not surprising that those group of birds had the highest cumulative weight gain. Protein, fat, ash and water gain were not different for the other treatments. Numerically broilers in continuous lighting that consumed mash had the lowest protein, fat, water and ash gain compared to the birds in 23L:1D that were fed pellets and those in 12L:12D that were fed either mash or pellets. Table 12 represents the main effects of light and feed form on body composition. When averaged over feed form, the mean values for broilers in restricted 12L:12D light gained more ($p<.01$) protein, (595 vs. 574g). Such restricted lighting programs decrease activity which allowed the birds to gain more fat (646 vs. 606g). These findings are in disagreement with Rahimi et al. (2005) who reported that restricted light reduced abdominal fat weight of both male and female chicks at 42D of age. Also Oyedeji and Atteh (2005) reported significant reduction in abdominal fat when broilers were exposed to only six hours of light as against the usual 12 hours of light per day. However Siopes et al. (1989) observed that the amount of abdominal fat was significantly greater in restricted light duration that included 8L:16D compared to continuous light of 23L:1D. Carcass water gain (2062 vs. 2000g) and ash gain (90 vs. 86g) were also higher in the birds in restricted light than continuous lighting.

Averaging over lighting schedules, pellet-fed birds had gained on average more ($p<.01$) protein (594 vs. 576g), fat (639 vs.613g). This agrees with the results of McKinney and Teeter (2004) which found pelleting could result in up to 187 kcal MEn/kg of ECV over mash than mash-fed broilers. Pellet fed birds also had greater ($p>0.07$) water (2063 vs.1999g) and ($p>0.09$) ash (90 vs. 87) content than mash-fed broilers. In a previous experiment, Plavnik et al. (1997) reported increased accumulation of carcass fat, associated with pellet feeding in broilers and turkey poults. Since pellet-fed birds spend less time feeding and visiting the feed trough, than mash fed birds, they spend most of their time resting which is estimated to be about 62.48% for pellet and 47.35% for mash as reported by Skinner-Noble et al. (2005) This suggests that when the birds are fed pellets, they rest more and conserve more of their energy intake and deposits in the form of fat and muscle development (Jensen et al., 1962). Mashes fed birds use more of the metabolizable energy intake for maintenance. Feed form effects on bone ash seems to be varied because in this study pellet increased bone ash more than mash while Kilburn 2001) observed a substantial reduction in bone ash in broiler chicks from feeding pellet. In a related experiment Kasim and Edwards (2000) reported that increasing maize particle size increased bone ash in broilers compared a diet containing fine particles.

The results of the statistical analyses and the means of protein, fat, ash and water express as a percentage of body weight due to the effect light and feed form are summarized the Table 13. There were no interaction between light and feed form for percentage protein, water, fat and ash. The birds in both lighting schedules that were fed either mash or pellet had similar percentage of body composition. Although percentage of bird protein was numerically lower for the birds in 23L:1D that were fed pellet, yet on the average bird protein for most of the treatments at 50D was estimated to be about 17-18%. The mean percentage of carcass fat was different among treatments. The birds in 12L:12D that consumed either pellet or mash contained on the average 19.2% fat which was significantly different p= .01 from the ones in 23L:1D that were fed either mash or pellet that contained on average 18.4% fat. Similar studies by Rahimi et al. (2005) suggested that the percentage of abdominal fat of 1L: a 3D chick was lower than that of continuous lighting. The estimated bird water was 61% for all the treatments.

The main effects of light and feed form and the results of the statistical analyses are summarized in Table 14. When averaged over feed form, neither light nor feed form had no effect on % protein composition. Broiler chicks in 12L:12D had acquired on average more ($p<.01$) fat (19.0% vs. 18.4%) than the birds in 23L:1D. Ohtani and leeson (2000) reported that the weights of abdominal fat pads, expressed as a percentage of carcass weight, when measured at 60d of age, were significantly ($p<.01$) heavier for IL chickens than continuous lighting. The fact that the birds in 12L:12D were fatter was expected because bird activity is lower in restricted lighting therefore energy for activity is diverted into fat. Light and feed form had no effect on percentage water which was estimated on the average to be 61% of body weight. Ash composition of 12L:12D birds had a mean percentage of 2.7% which was significantly higher ($p<.01$) than the birds in the 23L:01L which was 2.6%. Ash content was not affected by feed form but was estimated to be about 2.6%.

Composition and energy balance

Mean metabolizable energy intake (MEI), metabolizable energy retained, heat loss, together with values for metabolizable energy intake per gram of gain and heat production measured at 50D for the different treatments are summarized in Table 15. Metabolizable energy intake was estimated as starter feed consumption (g) *3050 kcal + grower feed consumption (g) *3.131 kcal + finisher feed consumption*3.174 kcal. Heat loss was calculated as Metabolizable energy intake – Retained energy. Retained energy was calculated as the sum of (fat mass x 9.31) and (protein mass x 5.65). There were significant interactions between light and feed form for metabolizable energy intake metabolizable energy intake per gram of body weight gain and heat loss. The birds in 23L:1D that were fed pellets had the highest $p=.008$ MEI of 18,536kcal/bird compared to both the birds in 23L:1D that were fed mash and also the birds in 12L:12D that were fed either mash or pellet which averaged 17,525kcal per bird. MEI per gram of body weight gain was the lowest $p=.01$ for the birds in 12L:12D that were fed pellets 5.1kcal/g compared to the other treatments combinations which averaged 5.4kcal/g body weight gain. Additionally, heat loss $p=.03$ was the lowest 8139kcal/bird when birds in 12L:12D were fed pellets and the highest $p=.01$ when the birds exposed to 23L:1D and fed pellets 9303 kcal/bird. There was no significant interaction between light and feed form for retained energy. Since the birds in 23L:1D that were fed pellet consumed the most feed it is not surprising that they had a greater ($p<.02$) metabolizable energy intake (18536 kcal) at the end of the trial. The majority of the total Metabolizable energy intake (MEI) occurred in the grower phase. Numerically the highest $p=.05$ energy retention were from the birds in 12L:12D that were fed pellets 9600 kcal per bird compared to the four treatment groups which averaged 8931 kcal per bird. High energy retention may be due to reduced requirements for maintenance energy. Broilers in 23L:1D that ate mash retained numerically the least energy among all the treatments. The birds retained energy response to continuous lighting with mash was expected. Earlier, Skinner-Noble et al. (2005) reported that broilers are more active when they are fed mash than pellet and it is also well known that bird activity is higher in the light than the dark and that the diversion of energy into maintenance reduces energy for gain which makes the bird more energy inefficient.

Mean metabolizable energy intake, retained energy, heat loss along with metabolizable energy intake to weight gain ratio for the main effects of the different treatments are summarized in Table 16. When averaged over feed form, the ME intake of restricted light chickens, did not differ from continuous light chickens at 50D of age. There were no differences in metabolizable energy intake between 12L:01D and 23L:1D on 50D, but the birds in continuous light had a numerically higher ($p>.10$) ME intake (16072 vs.15889 kcal) than the birds on restricted light probably because they had a higher feed intake. Ohtani and Leeson (2000) reported higher ME intake in chickens in intermittent lighting with 1L:2D schedule than continuous lighting (CL) schedule at 6 wk of age, but no significant differences at 8 wk of age. It can be concluded from these studies that the effect of restricted light on broiler ME intake may disappear after 42D. The birds in the 12L:12D lighting had a lower heat loss (8367 vs. 8988 kcal) therefore accumulating a higher retained energy (9342 vs. 8855kcal) than the broilers in the 23L:1D group. It is well known that when the lighting is reduced, birds are almost immediately observed to reduce their activity and produce less heat.

Averaging over lighting schedule, pellet-fed birds had a higher ($p< .01$) ME intake (16210 vs. 15751 kcal) than mash fed birds. Retained energy was not different ($p>0.12$) between the feed forms but broilers that consumed pellet had a numerically higher retained energy (9269 kcal) than the ones that consumed mash (8927 kcal). Higher retained energy was attributable to higher fat and protein gain that was observed during composition analysis. Bird activity was not monitored for this experiment but studies by Aerni et al. (2000) revealed that when pellets are fed, broilers spend less energy towards feather pecking rates, feeding bouts and other activities thereby leaving more time for rest. Similarly studies by Skinner-Noble et al. (2005) suggested that pellet –fed birds eat less often (4.25 vs. 18.81%) and resting more (62.48 vs. 47.35%) than those fed mash therefore decreasing bird activity associated with feed consumption may divert more calories from activity to tissue accretion (Jensen et al., 1962).

Table 17 represents the effect of feed from on net energy and heat loss expressed as a percentage of total metabolizable energy intake per bird. Light and feed form effect on effective caloric value (ECV) is also represented in Table 17. The ECV was calculated by the equation ECV = 3983.8 + 0.25857 * wt50d-849.33275*Cumulative FCR at 50 d McKinney and Teeter (2004) using the average of the starting and ending BW and the FCR. There were significant interaction between light and feed form for % net energy, %

heat loss. The group of broilers in 12L:12D lighting that were fed pellet had the highest p= .02 % net energy gain compared to the other treatments. This suggests that this group of birds were more efficient in that they had lower maintenance requirements

While those in 23L:1D that were fed either mash or pellet along with the group of birds in 12L:12D that were fed mash all had gained similar percentage net energy ranging from 49-51%. The 12L:12D pellet fed group had a higher percentage net energy because they had the lowest p = .02 heat loss which was on average 46%. There were no differences among the other treatment groups which ranged 49- 51% but numerically the birds in 23L:1D pellet fed had the highest % heat loss of 51% presumably due to a higher feed intake. Average ECV for the birds in 12L:12D that consumed pellet was significantly higher than all the other treatments and was estimated to be about 3474 kcal. Numerically the lowest ECV 3347 kcal was obtained by the birds in continuous light that were fed pellet.

The main effects of light and feed from on net energy and heat loss expressed as a percentage of total metabolizable energy intake and ECV are displayed in Table 18. The mean percentage net energy gain of birds in restricted light (53%) was significantly greater ($p<.01$) than that of birds in continuous light estimated as 50%. Similarly the mean percentage heat loss for the birds in 12L:12D was significantly lower ($p< .01$) than that of the birds in 23L:1D (47 vs. 50%) respectively. The ECV for broiler chicks in 12L:12D was also greater ($p<.01$) than that of the birds in 23L:1D lighting. Lighting benefits, calculated as the differential ECV between 12L:12D and 23L:1D, was 70 Kcal MEn/kg of ration. Earlier studies by Beker (2004) estimated an energy saving of 104

Kcal/ kg. Although the calculated ECV was higher in that study, the result of both studies reemphasizes another benefit of light restriction.

There were no significant differences in mean % net energy, % heat loss and ECV for the birds that were fed either pellet or mash. However numerically birds that were fed pellet had a greater % net energy gain (52 vs. 51%) but % heat loss was lower (48 vs. 49%) than the birds that were fed mash. Differential ECV between pellets and mash was 70 Kcal Men/g of ration which was calculated similar to that of light. Though the ECV differed ($p <.08$) between pellets and mash, the %Net energy for gain (NEg) was not significant. However, the directional response of %NEg did agree with the hypothesis that pelleting increased dietary energy available for gain by increasing resting and decreasing eating behavior McKinney (2005).

Light and feed form effect on O2, consumption Co2 and heat production 19-30 d

Carbon dioxide (CO_2) production and oxygen ($O_{2)}$ consumption was recorded on 19D, 20D, 24D, and 30D. The data collected (liters/hour) was used in the following Brouwer's equation to estimate heat production ($HP = 16.18 \times O_2$ consumed $+ 5.02 \times CO_2$ produced). Table 19 represents Oxygen consumption together with Carbon dioxide and heat production on an hourly basis from 19D to 30D. Oxygen (O_2) consumption, Carbon dioxide (CO_2) production and heat production (hp) increased with age such that the values for O_2, CO_2 and HP on 19D were significantly lower ($p<.01$) than the values on 30D. Oxygen is required for growth, maintenance and activity therefore increased growth necessitates increase O_2 and CO_2.

Mean heat production during the light and dark period of 23L:1D and 12L:12D light durations for 19D, 20D 24D and 30D are displayed in Table 20. On the average heat production was higher ($p<.001$) in the light than the dark for the four different days. On 19D, Restricted 12L:12D light broilers had higher ($p<.0001$) heat production (66.4 vs. 39.5 kcal/h) during the light period compared with the dark period. These results are in agreement with studies by Ohtani and lesson (2000) that showed similar response in broilers at 3wk of age. Similarly broilers in 23L:1D light duration also had higher ($p<0.001$) heat production in the light than in the dark for that same day. Similar results were observed on 20 D, 24D and 30D. Although no significant differences were observed in 12L:12D light duration, there were numerical differences that showed higher heat production in the light than the dark for that day. Feed form had no significant effect on heat production in the light or dark of the two light durations. The mean results of light and feed form effects on Oxygen consumption, Carbon dioxide production and heat production (kcal/h) as well as the results of statistical analysis are shown in Table 21. Carbon dioxide production (3.7 l/h) and Oxygen consumption (4.8 l/h) was the greatest $p= .01$ when the birds were raised in 23L:1D and fed pellets. This indicates that these birds were more active during that treatment because increase activity would increase requirements for oxygen consumption and high carbon dioxide output. The highest $p=.01$ mean heat production per hour also came from the birds in this group and was estimated to be 7.8 kcal which is an indication of increase activity. Since heat production was estimated from Co_2 and O_2 then increased mean values of O_2 and Co_2 for maintenance and activity will result in higher heat production. There were no differences in heat production as results of the other treatments.

CHAPTER IV

CONCLUSION

There are several important conclusions that can be drawn from this study. First of all from 16-35D, birds in continuous light that were fed pellets consumed the most feed and gained the most weight but the most efficient birds were those in restricted light that were fed pellet. Dissimilar to several studies, early light restriction seems to impair the performance of male broilers in the grower phase. The most noticeable difference in growth was that up to 35 d of age, when light restricted birds experienced delayed growth. This finding may be because more nutrients are used for growth rather than for maintenance. Restricted lighting depressed feed consumption, which ultimately hindered body weight gain, therefore allowing birds on continuous lighting to consume more feed and excel in weight gain. Similar initial depressions in the body weight gain by chickens subjected to light schedules have been reported by Ohtani and Leeson (2000).

The group of birds that were fed pellets had higher feed consumption, weight gain and were more efficient than birds fed mash. At that stage, broiler chicks performed the best when they have continuous light and are fed pellets.

From 35-42D light was more important for productivity than feed form because the birds in 12L:12D that were fed either mash of pellet adapted to restricted lighting and improved their performance. They ate more feed, gained more weight and were more efficiency compared to those in unrestricted light that consumed either mash or pellet.

During that phase, feed form had no effect on bird performance although birds that consumed pellets had a slightly higher weight gain and feed consumption than the birds that were fed mash. Although feed consumption was not different, light restriction allowed birds to gain more weight and made them more efficient than continuous light. The improvement in performance may be due to compensatory growth also it is well documented if sufficient time is allowed for adequate feed consumption, restricted lighting impacts feed efficiency by reducing activity.

When cumulative performance at 42D was analyzed, birds that were fed pellet in 12L:12D had similar body weight gain as pellet fed birds in 23L:1D that consumed more feed. Growth rate was increased, thus demonstrating the remarkable ability of the broilers at this age to increase feed intake in response to light.

Pellet fed birds in 12L:12D were the most efficient group of broilers at that stage since they may have rested more. In general birds performed better in restricted than continuous lighting and pellet fed birds had better body weight gain, feed consumption and feed efficiency than mash fed birds on 42D.

During the last week of the finisher phase, birds in 12L:12D that were fed pellets had gained the most weight and were numerically more efficient than the other treatments for that period suggesting that it is better to feed broilers pellets and restrict light from 42 to 50D of the finisher phase.

About the experiment as a whole the birds in restricted lighting that were fed pellets gained the most weight, consumed the most feed and were the most feed efficient, while those in continuous light that were fed pellets consumed the most feed but did not gain the most weight therefore making them the most inefficient. Broiler chickens reared in restricted lighting schedules showed a temporary growth delay early in the experiment but after adaptation, manifested catch-up growth during the subsequent period.

Metabolizable energy intake and heat loss was highest when birds were fed pellets in continuous light. It is probably due to the fact that continuous light increased the requirements for maintenance energy because there was a negative impact on retained energy. The most energy efficient birds were those in restricted light that were fed pellets because while having similar ME intake, they expended the least heat loss, had the most retained energy therefore requiring the least ME intake per body weight gain. The efficiency of utilization of metabolizable energy intake per gram of body weight gain was the highest as a result of restricted light.

The significance of light on energy efficiency was less important than feed form. Restricted light lowered heat production and increased retained energy compared to continuous light. The advantages of slowing down early growth and lower heat production attributed to restricted lighting can be of economic significance with regard to improved feed conversion efficiency. Although pellet increase ME intake, yet retained ME and heat loss was not different from that of mash but there was an inclination for pellets to have a better impact on energy efficiency than mash.

Although it was more efficient to feed pellet in restricted lighting, yet this treatment made the birds fatter. Increase carcass fat decreases dressing percentage and increases labor cost. Feeding mash in similar lighting reduced efficiency but resulted in similar fat deposition. Birds in continuous light that consumed mash or pellet had less fat deposition but efficiency was compromised.

It is concluded that feeding pellet to broilers in restricted light will initially delay growth but over time will exhibit compensatory gain. Feeding mash instead of pellets in similar lighting is not economically efficient. Light restriction slows the growth of broilers but that growth rate progressively increases over time to achieve complete growth compensation. Restricted light reduces activity therefore increases efficiency however increase fat deposits. Pellet increases growth and efficiency and by using mash diets at any time reduces growth rate.

From a consumer stand point we could speculate that the best use of light and feed form for improving edible product yield would be to feed mash when imposing restricted light because it made the birds leaner. Since pellet fed birds in restricted light were the most efficient, then from the producers stand point it would be better to use a 12L:12D lighting program and reduce the energy value of the diet by 70kcal. This would among other things reduce electric cost, improve feed efficiency, and may reduce fat deposition. However further studies are required.

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Table 1. Effects of lighting schemes and feed form on body weight gain (BWT gain), feed consumption (feed cons) and feed efficiency (Eff) of male broilers raised from 16 to 35 d.

light	Feed form	BWT gain[1] (g)	feed cons[2] (g)	Eff[3]
12L:12D	Mash	1468	2231 [c]	.66 [b]
12L:12D	Pellet	1566	2242 [c]	.70 [a]
23L:1D	Mash	1590	2377 [b]	.67 [b]
23L:1D	Pellet	1706	2502 [a]	.68 [b]

AOV		Probability	
Light	.0001	.001	.93
Feed form	.0002	.06	.004
L X F[4]	.67	.08	.12

[abc] Means within columns with different superscripts are significantly different ($p<0.10$).
[1] Body weight gain= body weight 35D- body weight 16D.
[2] Feed cons =feed consumption (cumulative feed consumption -16D feed consumption)
[3] Efficiency = body weight gain/feed consumption
[4] F= Feed, L= light

Table 2. Main effects of lighting schemes and feed form on body weight gain (BWT gain), feed consumption (feed cons) and feed efficiency (Eff) on male broilers raised from 16 to 35 d.

TRT	BWT gain[1] (g)	Feed cons[2] (g)	Eff[3]
Lighting program			
12L:12D	1517 [b]	2236 [b]	.68
23L:1D	1648 [a]	2439 [a]	.68
Feed form			
Mash	1529 [b]	2304 [b]	.66 [b]
Pellet	1637 [a]	2372 [a]	.69 [a]
AOV		Probability	
Light	.0001	.001	.93
Feed form	.0002	.06	.004
L X F[4]	.67	.08	.12

[ab] Means within columns with different superscripts are significantly different (p<0.10).
[1] Body weight gain= body weight 35D- body weight 16D.
[2] Feed cons =feed consumption (cumulative feed consumption -16D feed consumption)
[3]Efficiency = body weight gain/feed consumption
[4]F= Feed, L= light

Table 3. **Effects of lighting schemes and feed form on body weight gain (BWT gain), feed consumption (feed cons) and feed efficiency (Eff) of male broilers raised from 35 to 42 d.**

Light	Feed form	BWT gain[1] (g)	feed cons[2] (g)	Eff[3]
12L:12D	Mash	688	1471	.47
12L:12D	Pellet	694	1473	.47
23L:1D	Mash	598	1407	.42
23L:1D	Pellet	615	1489	.41
AOV			Probability	
Light		.0002	.43	.0001
Feed form		.52	.15	.69
L X F[4]		.73	.13	.34

[1] Body weight gain= body weight 42D- body weight 35D.
[2] Feed cons =feed consumption (42D feed consumption -35D feed consumption)
[3]Efficiency = body weight gain/feed consumption
[4]F= Feed, L= light,

Table 4. Main effects of lighting schemes and feed form on body weight gain (BWT gain), feed consumption (feed cons) and feed efficiency (Eff) of male broilers raised from 35 to 42 d.

TRT	BWT gain[1] (g)	feed cons[2] (g)	Eff[3]
Lighting program			
12L:12D	691[a]	1471	.47[a]
23L:1D	607[b]	1448	.42[b]
Feed form			
Mash	643	1439	.45
Pellet	654	1480	.44
AOV	Probability		
Light	.0002	.43	.0001
Feed form	.52	.15	.69
L X F[4]	.73	.13	.34

[ab] Means within columns with different superscripts are significantly different ($p<0.10$).
[1] Body weight gain= body weight 42D- body weight 35D.
[2] Feed cons =feed consumption (42D feed consumption -35D feed consumption)
[3] Efficiency = body weight gain/feed consumption
[4]F= Feed, L= light,

Table 5. Effects of lighting schemes and feed form on body weight gain (BWT gain), feed consumption (feed cons) and feed efficiency (Eff) of male broilers raised from 42 to 50 d.

light	Feed form	BWT[1] gain (g)	feed cons[2] (g)	Eff[3]
12L:12D	Mash	567	1244	.46[b]
12L:12D	Pellet	641	1318	.49[a]
23L:1D	Mash	562	1197	.47[b]
23L:1D	Pellet	568	1318	.43[b]
AOV			Probability	
Light		.22	.63	.32
Feed form		.20	.04	.90
LX F[4]		.26	.59	.08

[ab] Means within columns with different superscripts are significantly different ($p<0.10$).
[1] Body weight gain= body weight 50D- body weight 42D.
[2] Feed cons =feed consumption (50D feed consumption -42D feed consumption)
[3]Efficiency = body weight gain/feed consumption
[4]F= Feed, L= light,

Table 6. **Main effects of lighting schemes and feed form on body weight gain (BWT gain), feed consumption (feed cons) and feed efficiency (Eff) of male broilers raised from 42 to 50 d.**

TRT	BWT gain[1] (g)	Feed cons[2] (g)	Eff[3]
Lighting program			
12L:12D	604	1281	.47 [a]
23L:1D	564	1258	.45 [b]
Feed form			
Mash	564	1221[b]	.46
Pellet	604	1317[a]	.46
AOV		Probability	
Light	.36	.63	.32
Feed form	.20	.04	.90
L X F[4]	.26	.59	.08

[ab] Means within columns with different superscripts are significantly different ($p<0.10$).
[1] Body weight gain= body weight 50D- body weight 42D.
[2] Feed cons =feed consumption (50D feed consumption -42D feed consumption)
[3] Efficiency = body weight gain/feed consumption
[4] F= Feed, L= light,

Table 7. **Effects of lighting schemes and feed form on cumulative weight gain (Cum gain), cumulative feed consumption (cum feed) and cumulative feed efficiency(Eff) of male broilers from 16 to 42 d.**

TRT	Feed form	Cum gain[1] (g)	Cum feed [2](g)	Eff[3]
12L:12D	Mash	2156	3702 [b]	.58 [b]
12L:12D	Pellet	2260	3715 [b]	.61 [a]
23L:1D	Mash	2188	3784 [b]	.58 [b]
23L:1D	Pellet	2322	3990 [a]	.57 [b]
AOV		Probability		
Light		.23	.004	.04
Feed form		.004	.06	.02
L X F		.67	.07	.09

[ab] Means within columns with different superscripts are significantly different ($p<0.10$).
F= Feed, L= light, EFF = Efficiency, BWT = body weight
[1]Cum wt gain.= 42D body weight -16D body weight
[2] Cum feed = fed consumption from 16 to 42D
[3] Cum EFF = 16-42D body weight gain / 16-420D feed consumption

Table 8. **Main effects of lighting schemes and feed form on cumulative weight gain (cum gain), feed consumption (cum feed) and feed efficiency (Cum Eff) of male broilers raised from 16 to 42 d.**

TRT	Cum gain [1](g)	Cum feed [2] (g)	Cum Eff [3]
Lighting program			
12L:12D	2208	3708 [b]	.60 [a]
23L:1D	2255	3887[a]	.58 [b]
Feed form			
Mash	2172 [b]	3743 [b]	.58 [b]
Pellet	2291 [a]	3853 [a]	.60 [a]
AOV		Probability	
Light	.23	.004	.04
Feed form	.004	.06	.02
L X F[4]	.67	.07	.09

[ab] Means within columns with different superscripts are significantly different ($p<0.10$).
[1] Cum wt.= 42D body weight -16D body weight
[2] Cum feed = fed consumption from 16 to 42D
[3] Cum EFF = 16-42D body weight gain / 16-420D feed consumption
[4]F= Feed L= light

Table 9. **Effects of lighting schemes and feed form on cumulative body weight gain (Cum gain), feed consumption (cum feed) and feed efficiency (Eff) of male broilers raised from 16 to 50 d.**

light	Feed form	Cum gain [1] (g)	Cum feed [2] (g)	Eff[3]
12L:12D	Mash	2706	4946 [b]	.55 [b]
12L:12D	Pellet	2897	5033 [b]	.58 [a]
23L:1D	Mash	2702	4982 [b]	.54 [b]
23L:1D	Pellet	2813	5308 [a]	.53 [b]
AOV		Probability		
Light		.47	.03	.004
Feed form		.02	.007	.26
L X F[4]		.49	.07	.01

[ab] Means within columns with different superscripts are significantly different ($p<0.10$).
[1] Cum gain =cumulative body weight gain
[2] Cum fed = cumulative feed consumption
[3] Feed Eff= cumulative body weight gain/ cumulative feed consumption.
[4]F= Feed L= light,

Table 10. **Main effects of lighting schemes and feed form on cumulative body weight gain, (cum gain), feed consumption and cumulative feed efficiency (Cum Eff) of male broilers raised from 16 to 50 d.**

TRT	Cum gain[1](g)	Cum Feed [2](g)	Cum Eff3
Lighting program			
12L:12D	2801	4989 [b]	.56 [a]
23L:1D	2758	5145 [a]	.54 [b]
Feed form			
Mash	2704 [b]	4964 [b]	.54
Pellet	2855 [a]	5171 [a]	.55
AOV		Probability	
Light	.47	.03	.004
Feed form	.02	.007	.26
L X F[4]	.49	.07	.01

[ab] Means within columns with different superscripts are significantly different (p<0.10).
[1] Cum gain = BWT 50D – BWT 16D
[2] Cum feed = 16-50D feed consumption
[3] Cum EFF= cumulative efficiency
[4]F= Feed, L= light

Table 11. Effects of lighting schemes and feed form on protein, fat, water and ash of male broilers at 50 d.

Light	feed form	Protein (g)	Fat(g)	Water (g)	Ash (g)
12L:12D	Mash	581.2	626.7	2014.0	87.6
12L:12D	Pellet	609.0	665.4	2110.8	92.0
23L:1D	Mash	570.4	599.6	1984.3	85.6
23L:1D	Pellet	578.3	612.9	2014.8	87 .2
AOV		Probability			
Light		.05	.03	.08	.05
Feed form		.09	.13	.07	.09
L X F[1]		.34	.47	.35	.42

[1]F= Feed, L= light,

Table 12. Main effects of lighting schemes and feed form on protein, fat, water and ash of male broilers at 50 d.

TRT	Protein (g)	Fat(g)	Water (g)	Ash (g)
Lighting program				
12L:12D	595 [a]	646 [a]	2062 [a]	89.8 [a]
23L:1D	574 [b]	606 [b]	2000 [b]	86.4 [b]
Feed form				
Mash	576 [b]	613	1999[a]	86.7
Pellet	594[a]	639	2063 [b]	89.6
AOV		Probability		
Light	.05	.03	.08	.05
Feed form	.09	.13	.07	.09
L X F	.34	.47	.35	.42

[ab] Means within columns with different superscripts are significantly different ($p<0.10$).
F= Feed, L= light

Table 13. **Effects of lighting schemes and feed form on percentage protein, fat, water and ash gain in male broilers raised from 16 to 50 d**

Lighting Programs	Feed form	% protein	% fat	%water	%ash
12L:12D	Mash	18	18.9	60.8	2.7
12L:12D	Pellet	18	19.2	60.9	2.7
23L:1D	Mash	18	18.4	61.1	2.6
23L:1D	Pellet	17	18.4	60.7	2.6
AOV		Probability			
Light		.23	.005	.88	.03
Feed form		.41	.45	.53	.08
L X F[1]		.21	.46	.24	.16

[1]F= Feed, L= light,

Table 14. **Main effects of lighting schemes and feed form on percentage protein, fat, water and ash gain in male broilers raised from 16 to 50 d.**

TRT	% protein	% fat	%water	%ash
Lighting program				
12L:12D	18	19.0 [a]	60.9	2.7 [a]
23L:1D	18	18.4 [b]	60.9	2.6 [b]
Feed form				
Mash	18	18.7	60.9	2.6
Pellet	17	18.8	60.8	2.6
AOV		Probability		
Light	.23	.005	.88	.009
Feed form	.41	.45	.53	.90
L X F[1]	.21	.46	.24	.16

[ab] Means within columns with different superscripts are significantly different (p<0.10).
[1]F= Feed, L= light

Table 15. Effects of lighting program and feed form on ME intake, Me retained , heat loss(HP) and ME:Gain ratio of male broilers raised from 16 to 50 d.

Lighting program	Feed form	ME intake[1] (kcal/bird)	ME:gain[2] (kcal)	Ret. Energy[3] (kcal)	bird energy[4] Kcal/bird[4]	HP[5] (kcal
12L:12D	Mash	17397 [b]	5.3 [b]	9084	2.74	8594 [b]
12L:12D	Pellet	17673 [b]	5.1 [c]	9600	2.77	8139 [c]
23L:1D	Mash	17506 [b]	5.4[a b]	8771	2.70	8673 [b]
23L:1D	Pellet	18536 [a]	5.5 [a]	8939	2.70	9303 [a]
AOV		Probability				
Light		.03	.001	.03	.003	.001
Feed form		.007	.35	.12	.53	.72
L X F[6]		.07	.007	.43	.33	.004

[abc]Means within columns with different superscripts are significantly different ($p<0.10$).
[1] ME intake =metabolisable energy intake
[2] ME :gain = (ME intake/ g BWT gain)
[3] Ret. Energy (retained energy) = protein gain energy + fat gain energy
[4]Bird energy
[5] HP = ME intake - retained energy
[6]F= Feed, L= light

Table 16. Main effects of lighting schemes and feed form on ME intake, retained , heat loss and ME:Gain ratio of male broilers raised to 50 d.

TRT	ME intake[1] (kcal/b)	ME:gain[2] (kcal/bird)	Ret. Energy[3] (kcal/b)	Kcal/bird[4]	Heat loss[5] (kcal/b)
Lighting schemes					
12L:12D	17535 [b]	5.2 [b]	9342 [b]	2.76 [a]	8367 [b]
23L:1D	18021 [a]	5.4 [a]	8855[a]	2.70 [b]	8988 [a]
Feed form					
Mash	17451 [b]	5.4	8927	2.72	8634
Pellet	18104 [a]	5.3	9269	2.73	8721
AOV			Probability		
Light	.03	.001	.03	.003	.001
Feed form	.007	.34	.12	.53	.72
L X F[6]	.07	.007	.43	.33	.004

[abc]Means within columns with different superscripts are significantly different ($p<0.10$).
[1] ME intake = Metabolizable energy intake
[2] ME :gain = (ME intake/ g BWT gain)
[3] Ret. Energy (retained energy) = protein gain energy + fat gain energy
[4]Kcal/bird
[5] Heat loss = ME intake - retained energy
[6]F= Feed, L= light,

Table 17. **Effects of lighting schemes and feed form on ECV % net energy, % heat loss of male broilers raised from 16 to 50D**

Lighting programs	Feed form	% NEg/kg[1]	% Heat Loss[2]	ECV[3]
12L:12D	Mash	51.2 [b]	48.7 [a]	3365 [b]
12L:12D	Pellet	54.1 [a]	45.6 [b]	3474[a]
23L:1D	Mash	50.2 [b]	49.7 [a]	3352 [b]
23L:1D	Pellet	49.0 [b]	50.9 [a]	3347 [b]
AOV		Probability		
Light		.003	.003	.03
Feed form		.31	.31	.08
L X F[4]		.02	.02	.06

[abc]Means within columns with different superscripts are significantly different ($p<0.10$)

[1] % NEg/kg= Net energy for gain

[2] % Heat Loss = percentage heat loss

[3] ECV = Effective Caloric Value

[4]F= Feed, L= light

Table 18. **Main effects of lighting schemes and feed form on Effective Caloric value (ECV), % net energy, % heat loss of male broilers raised from 16 to 50 d.**

TRT	% NEg/kg[1]	% Heat Loss[2]	ECV[3]
Lighting schemes			
12L:12D	52.6 [a]	47.3 [b]	3419 [a]
23L:1D	49.6 [b]	50.3 [a]	3349 [b]
Feed form			
Mash	50.8	49.2	3358
Pellet	51.6	48.4	3410
AOV		Probability	
Light	.003	.003	.03
Feed form	.31	.31	.08
LX F[4]	.02	.02	.06

[ab] Means within columns with different superscripts are significantly different (p<0.10)

[1] ECV = Effective Caloric Value

[2] % NEg= Net energy Kcal/ ME kcal

[3] % Heat Loss = percentage heat loss

[4] F= Feed, L= light,

Table 19. Effects of age on Oxygen (O_2), consumption Carbon dioxide (Co_2) production and heat production (HP kcal/h) per bird of male broilers for 24hours

Day	Co2 prod[1] (l/h)	O2 con [2] (l/h)	HP [3] (kcal/h)
19	1.9 [c]	2.5 [d]	4.1 [d]
20	2.7 [b]	3.5 [c]	5.6 [c]
24	3.9 [a]	4.7 [b]	7.6 [b]
30	4.3 [a]	5.7 [a]	9.1 [a]

[abc] Means within columns with different superscripts are significantly different ($p<0.05$)
[1] Co_2 prod = Carbon dioxide
[2] O_2 con = Oxygen consumption
[3] HP = Heat production

Table 20. Heat production from male broilers in the light and dark periods of restricted and continuous light duration on 19 d , 20 d, 24 d and 30 d.

Day of age	Light duration	HP light[1]	HP dark[2]	Probability	Daily HP[3]
19	12L:12D	66.4 [a]	39.5[b]	.001	105.9
	23L:1D	123.8 [a]	2.0 [b]	. 0001	125.8
20	12L:12D	74.1 [a]	55.9 [b]	.001	130.0
	23L:1D	128.2 [a]	5.7 [b]	.001	133.9
24	12L:12D	117.3 [a]	58.1 [b]	.001	175.4
	23L:1D	204.1 [a]	9.6 [b]	.001	213.7
30	12L:12D	122.0 [a]	106.1 [a]	.001	228.1
	23L:1D	218.3 [a]	9.1 [b]	.001	227.4

[ab] Means within columns with different superscripts are significantly different ($p<0.10$)
[1] HP light = Heat production in the light
[2] HP dark = Heat production in the dark
[3] Daily HP = daily heat production

Table 21. **Effects of lighting programs and feed form on O_2 consumption, CO_2 production, heat production per bird of male broilers raised from 16 to 50 d with 16 d.**

Lighting program	Feed form	Co2 prod [1].(l/h)	O2 Cons [2](l/h)	HP [3](kcal/h)
12L:12D	Mash	3.1^{b}	4.1^{b}	6.5^{b}
12L:12D	Pellet	2.9^{b}	3.7^{b}	5.9^{b}
23L:1D	Mash	3.1^{b}	4.0^{b}	6.5^{b}
23L:1D	Pellet	3.7^{a}	4.8^{a}	7.8^{a}
AOV		Probability		
Light duration		.04	.08	.07
Feed form		.35	.52	.50
L X F[4]		.08	.07	.07

[ab] Means within columns with different superscripts are significantly different ($p<0.10$).
[1] Co_2 prod.(l/h) = Carbon Dioxide production liter/hour)
[2] O_2 cons (l/h) = Oxygen consumption (liter/hour)
[3] HP(kcal/h) = Heat production (kilo calories/ hour)
[4]F= Feed, L= light

VITA

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